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NUCLEAR FLASH EYE EFFECTS TECHNICAL REPORT FOR
MILITARY PLANNERS

RALPH G. ALLEN, JR.

DAVID E. JUNGBAUER

DONALD J. ISCITT

BRIAN E. ARMENT

JOHN A. RUSSELL

FEBRUARY 1967

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas

Lt Col Dan Brown
HQ AFM&A/SGPT
202-767-5003
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USAF #435

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Allen, R. G., Jr., D. E. Jungbauer,
D. J. Isgitt, B. E. Arment, and J. A. Russell

*This work was supported by the Department of Ophthalmology, Air Force School of Aerospace Medicine, Brooks Air Force Base, Texas and the Medical Division, Defense Atomic Support Agency, Washington, D. C.

FOREWORD

This report was prepared by personnel of the Life Sciences Division of Technology Incorporated--

Ralph G. Allen, Jr., Ph. D.

David E. Jungbauer, B.S.

Donald J. Isgitt, B.S.

Brian E. Arment, B.A.

John A. Russell, M.S.

This research was performed for the U. S. Air Force under Task 630103 and under Program Element 6.16.46.01.D, Project 5710, Subtask 03.138, and was partially funded by Defense Atomic Support Agency. Mr. E. O. Richey, SAM, was Contract Monitor during the contractual period. Grateful acknowledgement is made of the assistance provided by Mr. E. O. Richey and Captain J. E. Hamilton of the Ophthalmology Branch.

Other major contributors to the effort were Messrs. R. A. Schmall and A. F. Muller of Technology Incorporated. Acknowledgement is also made of the contribution of Oskar L. Ritter, Ph. D., Office of the Chief Scientist, School of Aerospace Medicine for his atmospheric transmission model which takes into consideration the curvature of the earth.

ABSTRACT

This report is intended to be used as an aid to military mission planners in determining allowable proximity to a nuclear fireball from the standpoints of permanent retinal injury and the temporary effects of flashblindness. Pertinent physical and physiological phenomena are discussed in moderate detail; the nucleus of the work being a family of curves which indicate acceptable separation distances for the prevention of retinal burns and flashblindness. Detailed instructions for approximating acceptable separation distances using a slide rule are included as an appendix.

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I. INTRODUCTION

It has been known for many years that damage to the eyes can occur as a result of viewing a very bright light, and that this damage could result in a permanent loss of visual acuity. The early evidence of retinal damage produced in this way was observed in individuals who had viewed a solar eclipse without adequate eye protection⁽¹⁾. The resulting loss in vision was called "eclipse blindness", and even now despite frequent warnings to the public, injuries from viewing eclipses are still reported⁽²⁾.

The development of nuclear weapons introduced a new and potentially more hazardous source of radiation capable of producing eye injuries. The potential for eye injury was recognized from the beginning since protective goggles were worn at the first atomic bomb test in 1942--and in each test thereafter.

The first experiments dealing with the effects of a nuclear flash on the eyes were conducted by the Air Force School of Aviation Medicine in 1951 during Operation Buster. It appears, however, that this problem was not discussed in the open literature until 1953 when it was pointed out⁽³⁾ that, because of the focusing of energy by the eye, injury could be sustained at extremely long distances--much longer distances than those at which could be produced by any other direct effects.

Following Operation Buster came a series of studies to study the effects of nuclear detonations on vision. Th

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culminated with an extensive experiment conducted during Operation Dominic and Fishbowl in 1962⁽⁴⁾.

Today, there are several sources of radiant energy that are capable of producing retinal damage, and most of these sources possess a much greater capacity for producing damage than does the sun. With the exception of the Q-switched laser--an ultra-high power mode of laser operation that introduces a new spectrum of biological damage^(5, 6)--the mechanism by which injury to the eye is produced appears to be the same in all cases, viz., the production of regions of elevated temperatures in the retina and adjacent regions as a result of absorption of the incident radiation energy. Since permanent injury appears to be simply a consequence of generating excessive temperatures, no matter whether the source is the sun, a nuclear detonation, a normally operated laser, a pulsed xenon tube, an incandescent plasma, or some other high intensity source, the damage produced will be similar in each case--differing only as a result of variations in the conditions of exposure, differences in the characteristics of the sources, and differences in the subjects themselves.

The significance of chorioretinal burns depends upon a number of factors. Some of these factors are associated with the physical characteristics of the actual lesions--such as size, location, and severity. These factors determine the particular visual function affected and the extent of loss of function. In contrast, other factors involve the consequences of having

suffered a loss of visual function. These factors deal with the importance to the individual of the specific function affected, the extent of the functional loss, the possibility of partial recovery, and the potential for partly overcoming the loss by visual training and/or practice.

II. GENERAL DISCUSSION

This report was developed for use in determining acceptable proximity to nuclear detonations in so far as eye effects are concerned. Two potential mission hazards are dealt with - retinal burns and flashblindness. Weapon yields from .01 KT to 25 MT at burst and flight altitudes ranging from sea level to 100,000 feet have been considered.

The distances determined using the retinal burn envelopes are the minimum allowable distances from fireball to observer that are considered "safe", i. e., distances at which no permanent damage will be produced before a reflexive blink occurs and protects the eye.

The distances determined using the flashblindness envelopes are also minimum allowable distances, but in this case, they refer to temporary rather than permanent visual impairment. These curves describe the distance at which 10 seconds of flashblindness will be experienced, i. e. distances at which it will take 10 seconds to recover at least 20/120 acuity, sufficient acuity to obtain useful information from flight instruments.

Weapon characteristics, atmospheric transmission, and pertinent aspects of the physiology of vision are discussed cursorily in order to acquaint the reader with the basic concepts involved and to relate retinal exposure to loss of visual function.

To the extent possible, the prediction techniques employed incorporate the results of observations taken during the most recent nuclear tests ⁽⁴⁾.

Weapon Characteristics

There are several basic differences between nuclear and conventional high-explosive weapons. A nuclear explosion may be many times more powerful than the largest conventional explosion, a nuclear explosion is accompanied by highly penetrating ionizing radiations, the fission products remaining after a nuclear explosion are radioactive, and a large amount of the nuclear energy is converted to thermal energy (light and heat). This thermal energy is the energy that is responsible for chorioretinal burns and flashblindness.

Figure 1 shows the distribution of energy from a fission weapon in a typical air burst. For detonations in the atmosphere below 100,000 feet the fraction of energy converted to thermal energy lies between 30 and 40 percent ⁽⁷⁾ and is taken as 33 percent in the calculations described herein.

At lower altitudes, a gaseous fireball is formed and essentially all of the thermal energy is emitted in two pulses (Figure 2) ⁽⁷⁾. The first

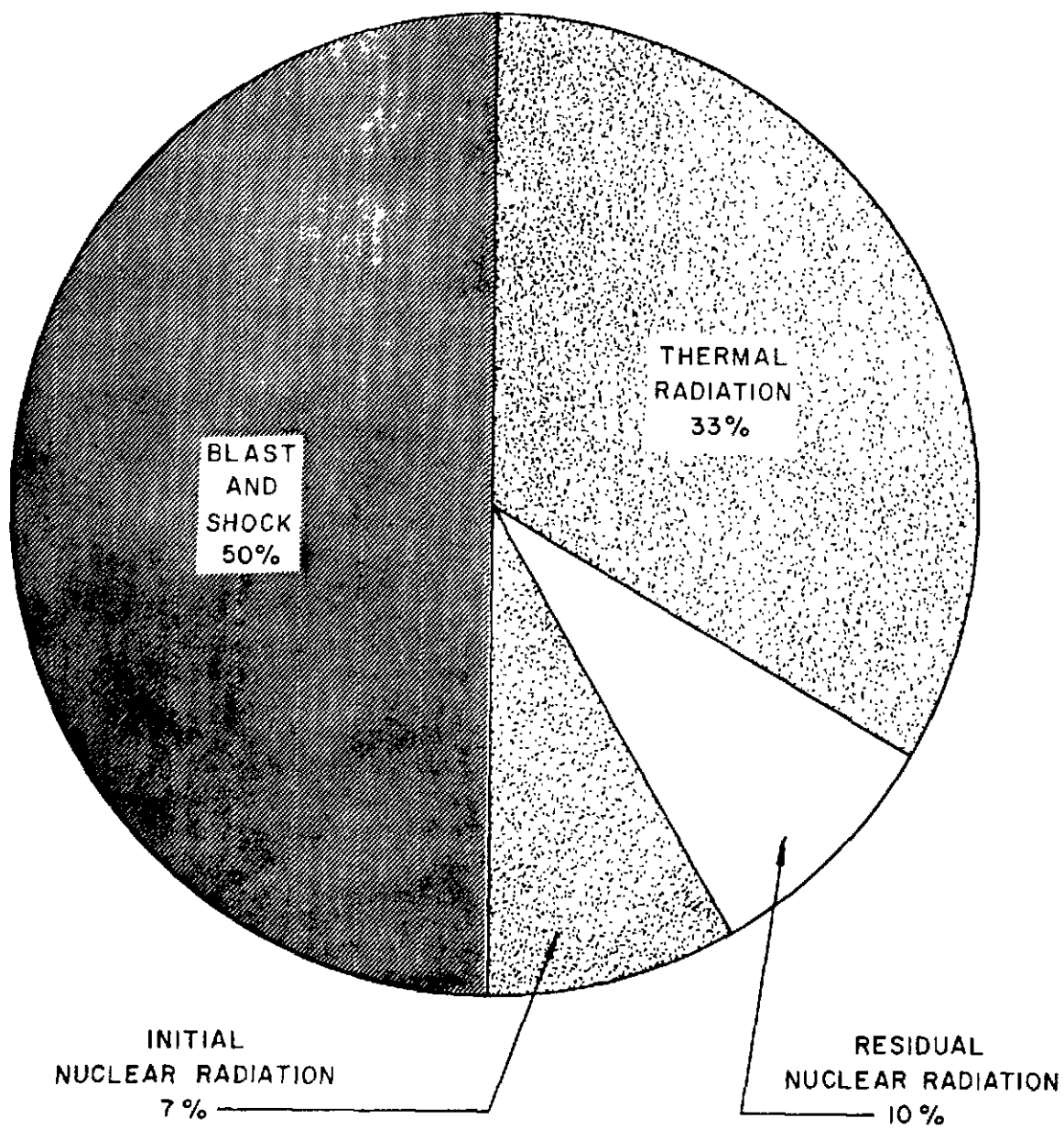


FIGURE 1. Distribution of energy in a typical air burst

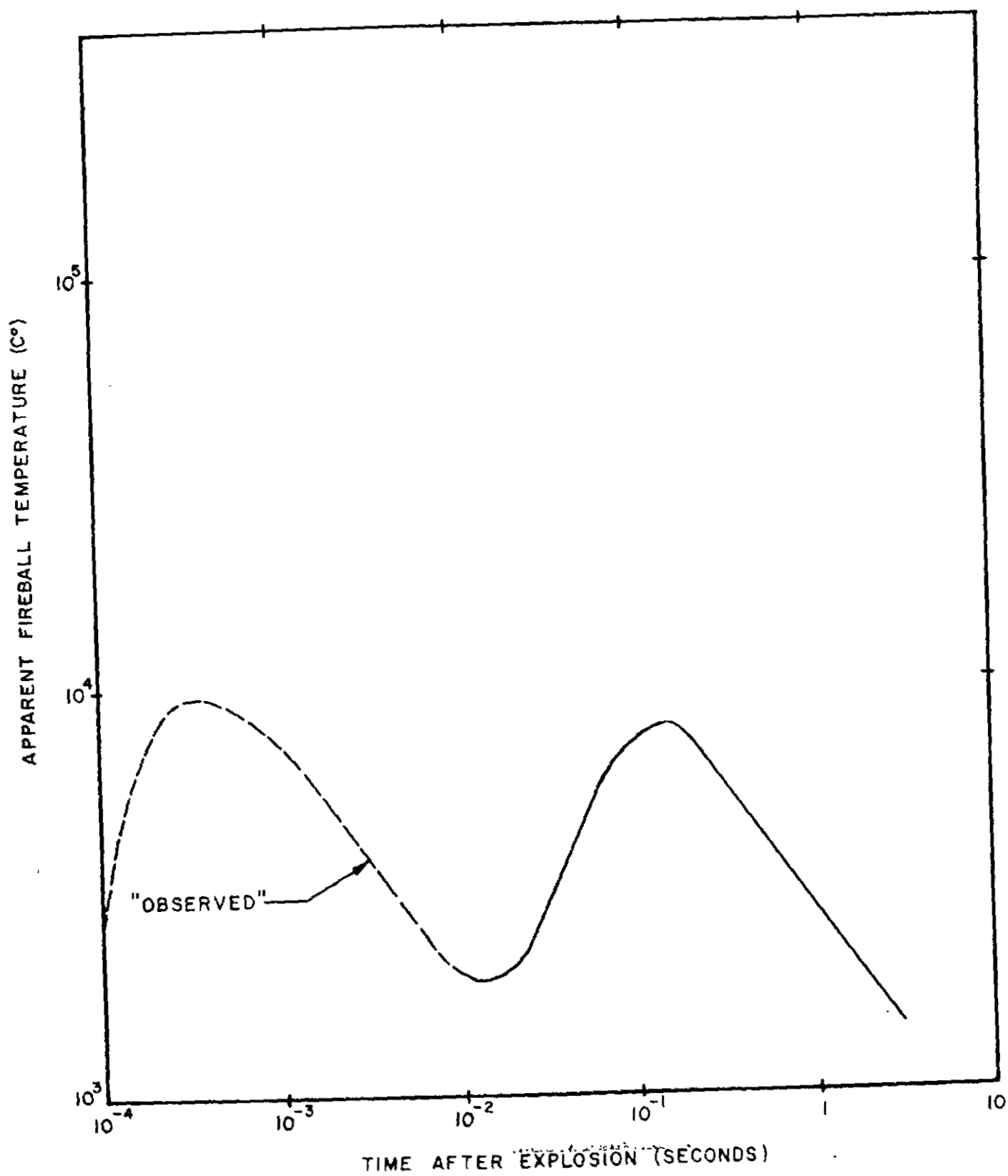


FIGURE 2. Temperature variation in a 20 kiloton air burst

pulse is relatively short and contains approximately one percent of the total energy. The second pulse, which contains the remainder of the energy, is much longer. Although the first pulse contains only one percent of the energy, under certain circumstances it is capable of producing permanent injury to the retina. For detonations at higher altitudes, more of the thermal energy appears in the first pulse. For very high altitude detonations, essentially all of the energy is emitted in a single very short pulse.

The amount of thermal energy arriving at the position of the observer depends upon the weapon design, its size, altitude of the detonation, distance to and altitude of the observer, and characteristics of the intervening atmosphere. Estimation of this energy comprises a large part of the problem of predicting safe separation distances.

Atmospheric Transmission

Before reaching the eye, the radiant energy emitted by the fireball is attenuated by the atmosphere through processes of scattering and absorption. Attenuation by the atmosphere is a subject of some complexity due to the variety of phenomena and situations which can be involved. In general, attenuation of radiant energy by the atmosphere depends upon the composition, characteristics, and distribution of the atmosphere in the path between detonation and observer and the energy spectrum of the emitted radiation. The composition, distribution, and characteristics of the atmosphere vary from time to time and place to place and frequently are difficult or impossible

to predict with any accuracy. For the retinal burn problem, it is not necessary to consider all of the phenomena involved, or to account for the full range of situations and variations which can occur. It is sufficient to limit consideration to the unscattered or image forming radiation transmitted through a clear cloudless atmosphere, the situation most favorable to the production of retinal burns, under the assumption that transmission through the atmosphere may be described adequately by the expression:

$$T_{AT} = \exp \left[-k_A^{\text{eff}} m \right] \cdot \exp \left[-k_w^{\text{eff}} w \right]$$

where:

m = the mass of air in the path between detonation and observer
(a function of burst and observer altitudes and horizontal range).

w = the mass of precipitable water vapor in the path between detonation and observer (also a function of burst and observer altitudes and horizontal range).

k_A^{eff} = effective narrow beam extinction coefficient of dry air.

k_w^{eff} = effective narrow beam extinction coefficient of water vapor.

The Standard U. S. Atmosphere (1962) is used as a model for air density variation with altitude whereas an exponential decrease with altitude is assumed for water vapor density.

Interaction of Radiant Energy with the Eye

The effects of thermal radiation on the eyes may be classified as permanent (chorioretinal burns) or temporary (flashblindness). Concentration of thermal energy on the retina by the eye lens system can result in injury to the retina. However, this will normally occur only if the source of energy is in the field of vision so that an image of the source is formed on the retina. Because of the focusing of energy by the eye, the distances at which chorioretinal burns can occur may be much greater than those where thermal radiation produces skin burns. This comes about as follows: the irradiance (energy per unit area per unit time) incident on the eye is inversely proportional to the square of the distance from the fireball. However, the area of the fireball image on the retina is also inversely proportional to the square of the distance from the fireball. As a result, the irradiance at the retina in the image of the fireball is independent of the distance from the fireball--except for the effect introduced by atmospheric attenuation. Fortunately, atmospheric attenuation increases with distance so that distance can provide protection. There are two other factors which enter into the problem in a significant way--one is pupil size and the other is blink time. In order to admit more light, the pupil of the eye normally enlarges at low levels of illumination. Thus, under conditions of low ambient illumination (dusk or night) the pupil will be larger than in daylight and allow more of the thermal energy from the fireball to strike the retina. Average pupil diameters assumed for this work were 6.5 mm (night); 5 mm (behind 2% gold filter), and 2.5 mm (day).

Considering blink time, it is apparent that only radiation received prior to closing the eyes in a reflexive blink can contribute to the production of retinal damage. As a result, the time for a blink to occur can be important. For the predictions made herein, exposure times are taken to be 250 milliseconds for small weapons and 450 milliseconds for larger weapons.

III. RESULTS OF EXCESSIVE EXPOSURES

Chorioretinal Burns

A sketch of the human eye is shown in Figure 3. For purposes of discussion, the eye may be compared to a camera. Light rays received by the eye are refracted by the cornea, lens, and ocular media so that they are focused on the retina producing there an image of the fireball.

Mechanism of Production

Heat generated in the retina and adjacent structures will in time diffuse away from the area in which the image is focused and will also be conducted away by the flow of blood in the vascular bed. If the rate of heat diffusion in an area is less than the rate of heat generation in that area, the temperature will increase. If the temperature exceeds the biological tolerances for the area involved, injury to the photo-receptors (rods and cones), to the optical nerve tissue and other structures in the retina and choroid may result--with a subsequent permanent loss of vision. Current research efforts are attempting to define threshold temperatures but relatively little reliable

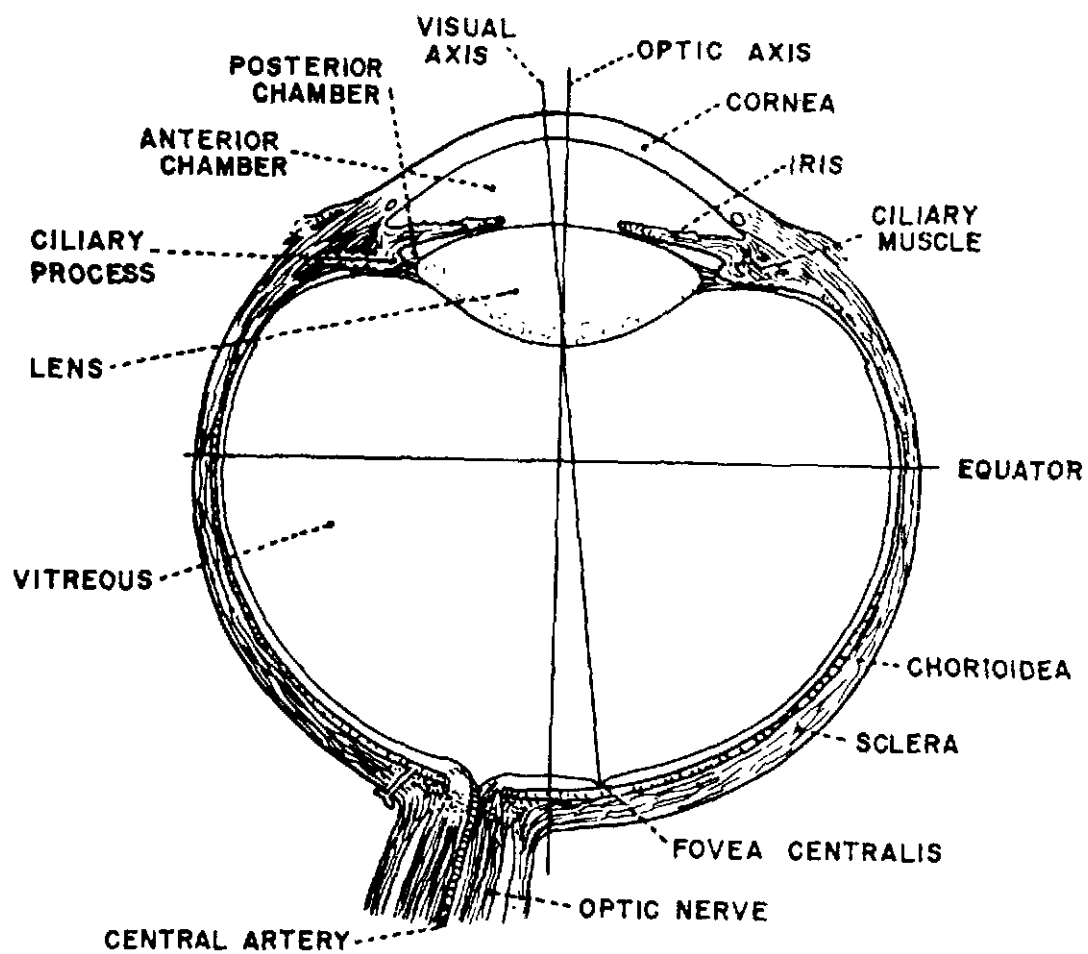


FIGURE 3. Schematic drawing of eye

quantitative information exists at present. Until more knowledge is gained in this area, it will be necessary to continue to base threshold criteria upon visual observations of retinal changes produced in laboratory animals and, with appropriate safety factors, extrapolate these results to humans.

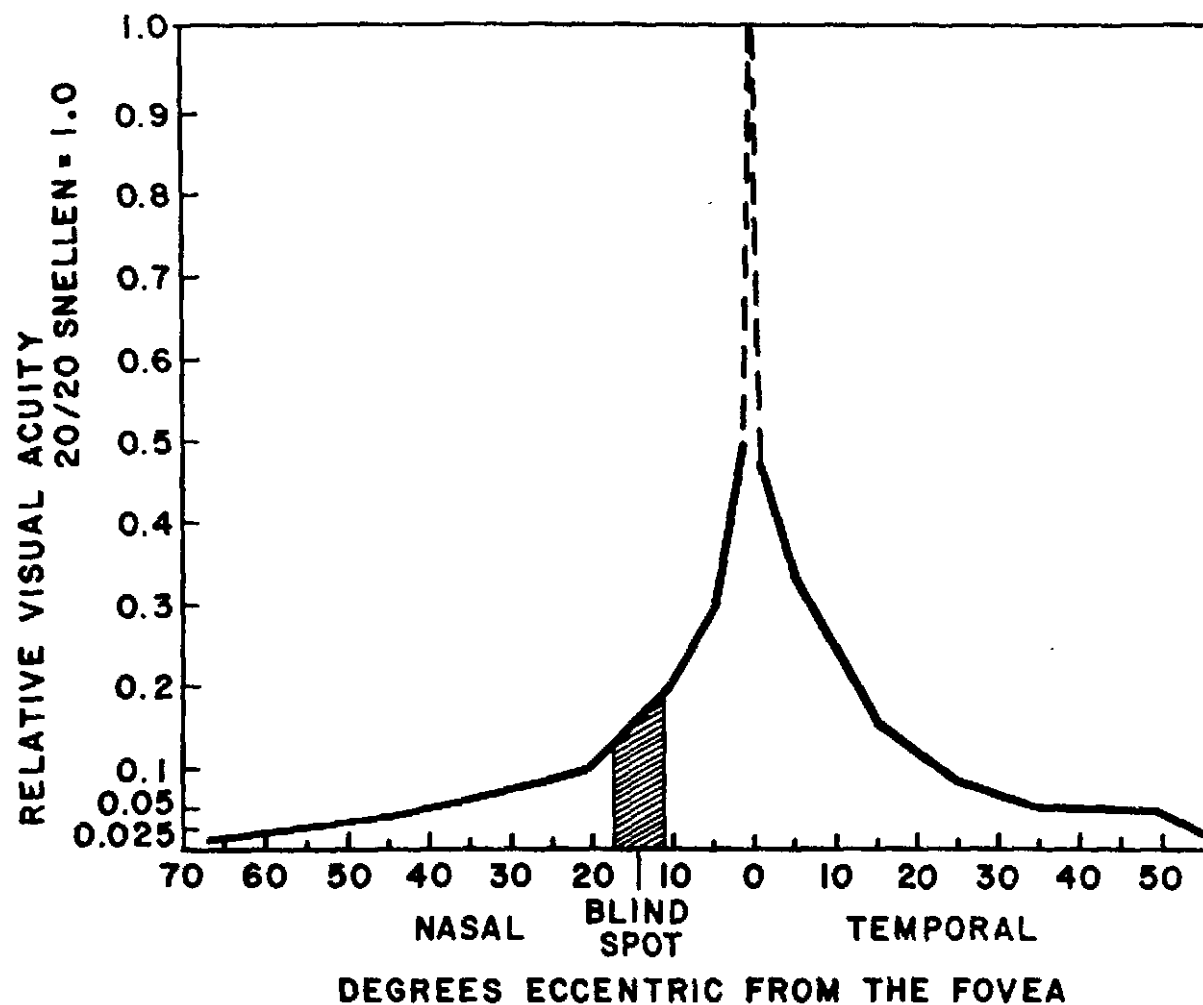
Effects on Vision

The degree of visual impairment caused by a retinal burn will be dependent on the size, severity, and location of the burn. The size of the image, which influences the size of a burn, depends on the visual angle subtended by the object--i.e., the size of the fireball and its distance from the observer. The severity of a burn depends in general upon the amount by which the exposure exceeds the threshold exposure. The function affected will be determined by the location of the burn(s). For example, sustaining a burn in the fovea would be most detrimental to visual acuity and color vision since the fovea is employed for high acuity and color recognition. A burn in the periphery would have less effect on visual acuity, and, barring complications, could result in a scotoma or blind spot that might not be noticed. From Figure 4, it can be estimated that burns exactly centered in each fovea and large enough to include the central 2.5 degree visual field, would reduce visual acuity to about 57 percent of normal (20/35 on the Snellen scale). In theory, if the central 10. degree visual field were destroyed, the

acuity would be 29 percent (20/70). Even if the central 20 degrees of vision were destroyed, an extremely unlikely situation, visual acuity would be reduced to approximately 20 percent, i.e. about 20/100.

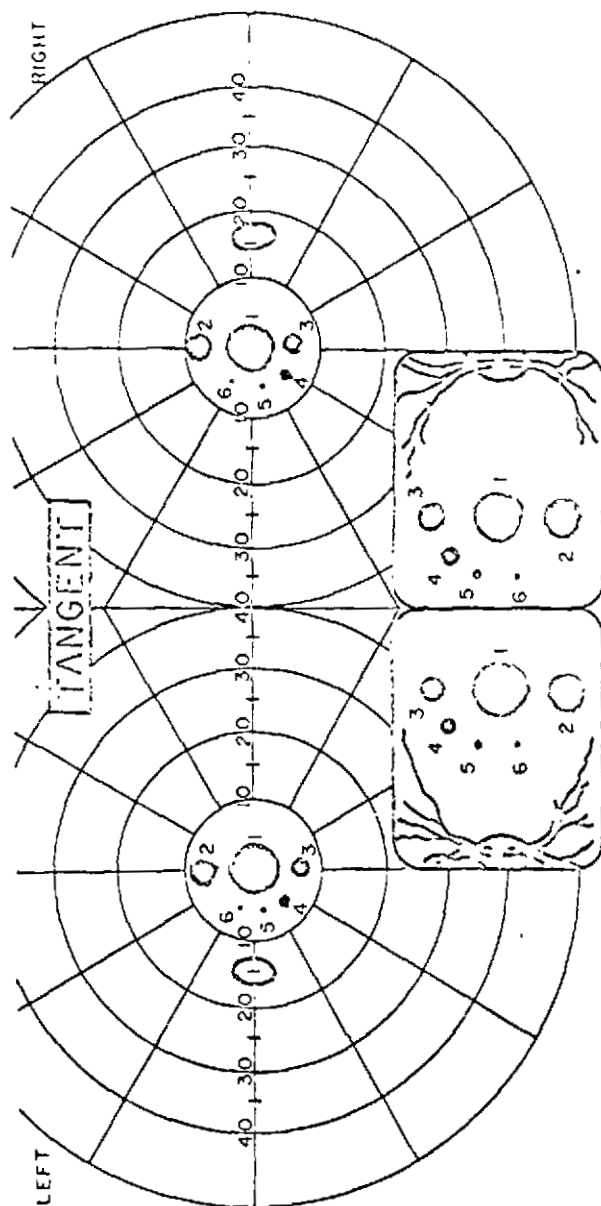
A schematic drawing of central field defects and the burns responsible for these defects are shown in Figure 5. The burns numbered 1-6 are shown in the region of the macula as they would appear in size and relation to the optic nerve. Burns having corresponding numbers result from a bilateral view of a single source. Corresponding scotomata are plotted on the field charts. The centrally located 1.8 mm (6 degree) burn would cause a permanent visual impairment of approximately 1/2 to 3/4 of normal if centered on the fovea. Visual acuity would probably be no better than 20/60 even after edema has subsided. Burns located off the fovea should not reduce acuity, but only produce blind spots.

Extra-foveal burns may produce visual defects that are significantly different than foveal burns. Since a lesion of the nerve fiber layer produces a defect which corresponds to the area which is served by the affected fibers and not the area of the lesion, a small heavy burn near the disc could cause an extensive field defect as well as a localized scotoma at the site of the burn. The course of the nerve fibers of the retina are shown schematically in Figure 6. Figure 7



The regional variations of the visual acuity (after Wertheim)

FIGURE 4. Visual acuity as a function of angular distance from the fovea.



1. - 1.8 mm BURN CAUSING CENTRAL SCOTOMA OF 6°
2. - 1.35 mm BURN CAUSING PARACENTRAL SCOTOMA OF 4.5°
3. - .9 mm BURN CAUSING PARACENTRAL SCOTOMA OF 3°
4. - .45 mm BURN CAUSING PARACENTRAL SCOTOMA OF 1.5°
5. - .15 mm BURN CAUSING PARACENTRAL SCOTOMA OF 0.5°
6. - .07 mm BURN CAUSING PARACENTRAL SCOTOMA OF 0.25°

FIGURE 5. Schematic drawings of bilateral burns and resulting visual field defects.

shows field defects produced by damage to nerve fiber bundles.

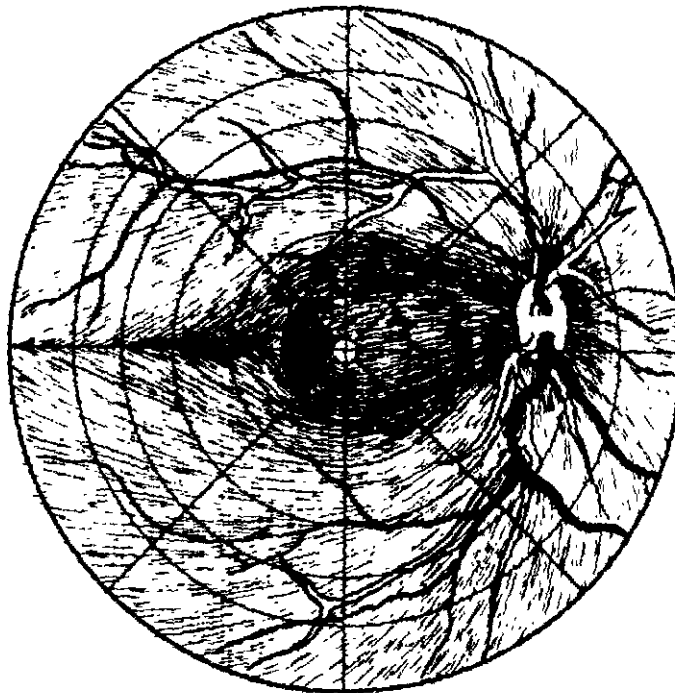
It should be emphasized that the loss of vision resulting from retinal burns although permanent and uncorrectable, will not take the form of total blindness. Burns can result in some impairment of vision in the form of blind "spots", but complete visual incapacitation as a result of retinal burns is extremely unlikely.

Flashblindness

The temporary decrease in visual sensitivity following exposure to a bright light has been termed flashblindness, and the time required to regain visual function is called recovery time. In considering recovery time, it is necessary to specify the visual task or the particular visual capability desired since the time required to reach a given level of visual performance depends upon the performance level selected.

Mechanism of Production

Briefly, high-luminance lights produce afterimages of the shape and size of the primary images. The initially perceived brightness of an afterimage is related to the amount of photo-pigment bleached in the area covered by the image, and the decrease in afterimage brightness with time appears to be related to the regeneration of the photo-pigments. An afterimage appears as a bright area in the visual field (or a dark area--depending upon the luminance of the background) and reduces



THE RADIATING LINES SHOW HOW THE NERVE FIBRES FAN OUT.
NOTE THAT TEMPORAL TO THE MACULA THE FIBRES MEET IN A
MEDIAN RAPHE.

Semidiagrammatic picture of the Fundus Oculi, right Eye.

FIGURE 6. Schematic drawing of the nerve fibers

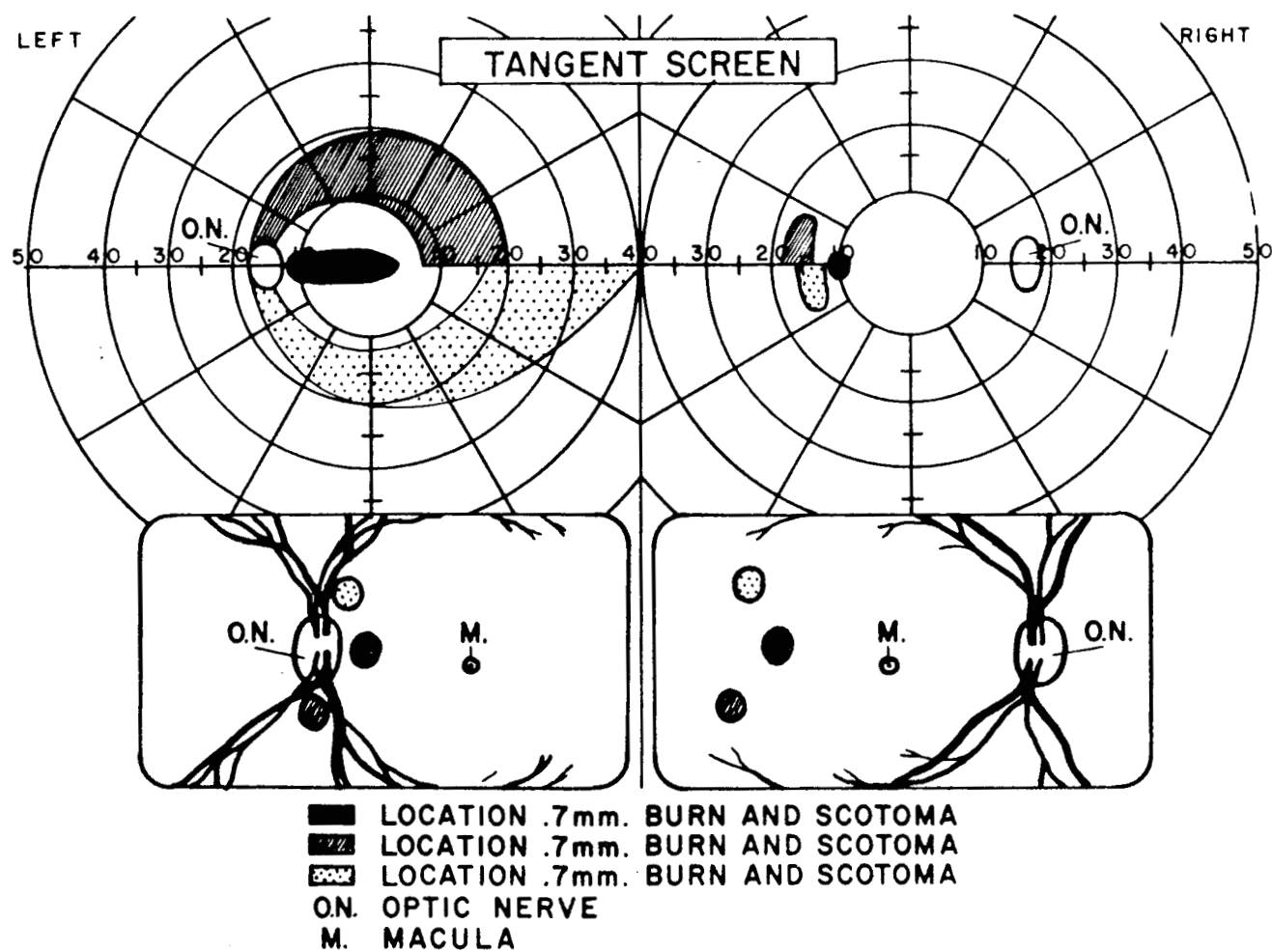


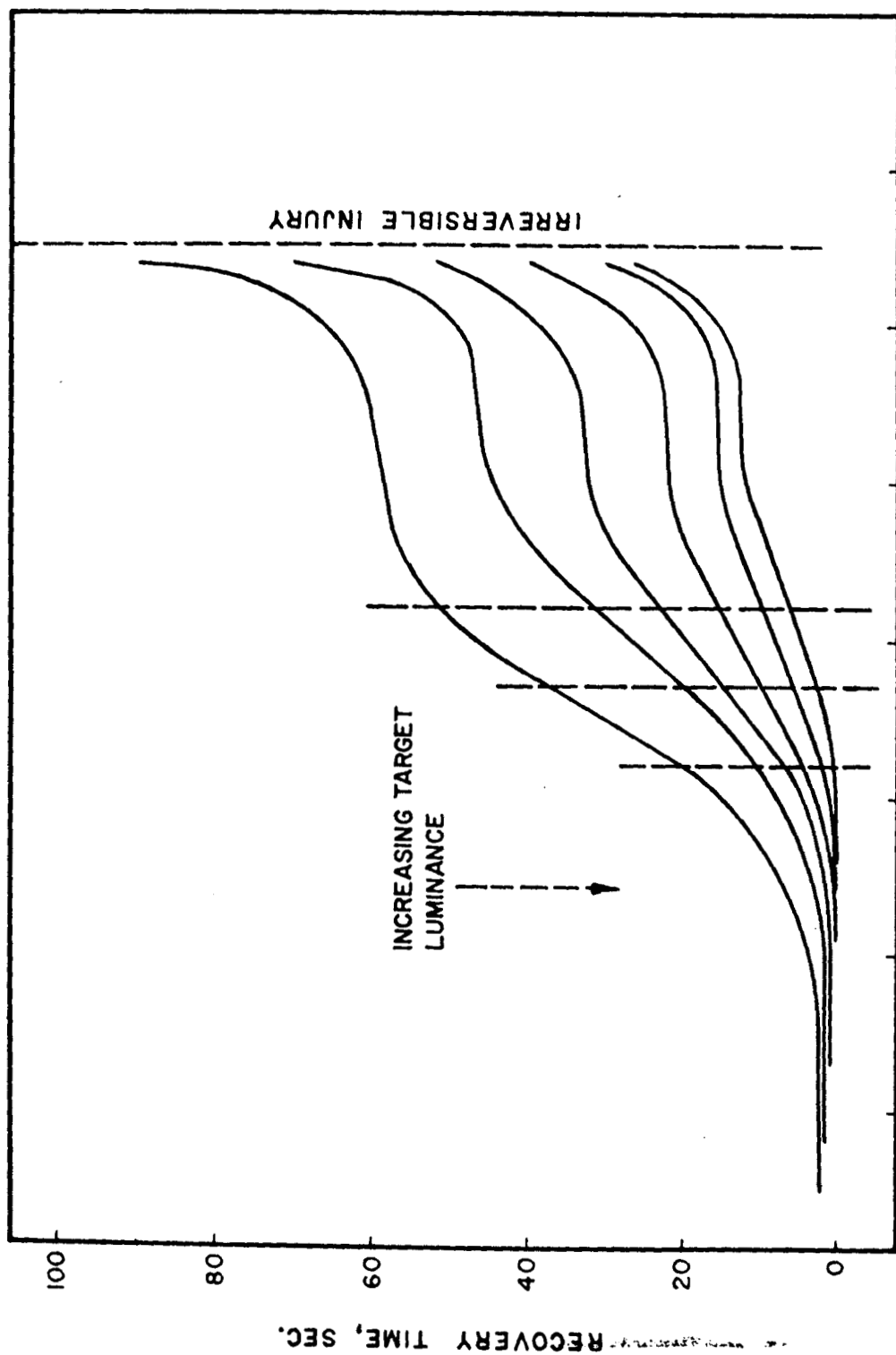
FIGURE 7. Schematic drawing of visual field defects resulting from injury to nerve-fiber bundles

contrasts in a scene subsequently imaged within the area occupied by the afterimage. In order for an object to be seen "through" the afterimage, the object must produce a primary image of sufficient brightness to create detectable contrasts. Against the background of an afterimage, detail that could be detected prior to a flash may be indistinguishable until the afterimage decays to a brightness level permitting perceivable contrasts. As a result, recovery time depends generally upon the integrated incident luminous energy, the luminance of the subsequent scene, and the visual acuity required for perception of the particular detail desired.

Effects on Vision

Figure 8⁽⁸⁾ shows the general form of recovery time as a function of stimulus flash energy--assuming a constant flash duration. Target luminance is the parameter between curves. For very low flash energies, there will be no significant effect on visual function. However, as flash energy is increased, an increase in recovery time becomes apparent. For exposure levels beyond those at which maximum bleaching occurs, recovery times may change very little with an increase in flash energy. However, as the flash energy approaches the threshold for injury, recovery time increases rapidly until injury occurs. At this point, function is lost irreversibly.

The relationship between target luminance and recovery time can also be inferred from an examination of Figure 8. Increasing display



LOG STIMULUS

FIGURE 8. Effect of flash energy and display luminance on flashblindness recovery time

luminances are represented by successively displaced curves in the figure. Note that recovery times decrease with increasing target luminance. Clearly, target luminance is an important variable and recovery times can be significantly reduced by increasing target luminance.

IV. PREDICTION METHODS

Retinal Burn

Detailed calculations illustrating the techniques employed in determining acceptable separation distances are given in Appendix A. A brief summary of the method is given below:

The total energy per unit area focused into an image on the retina is called the retinal exposure, Q_r (CALC). This quantity varies inversely as a function of distance to the fireball due to atmospheric attenuation and can be calculated for the human eye--provided atmospheric attenuation and the thermal characteristics of the weapon are known. For the curves contained in this document, a blink reflex of 0.25 seconds is assumed for yields below 1 MT and 0.45 seconds for yields of 1 MT and above.

Experiments using rabbits, plus data obtained from limited studies involving humans, serve as the basis for determining the allowable or safe retinal exposure, Q_r^T . This is the maximum exposure for which no

burn will be produced (9).

From a practical standpoint, concern over retinal burns occurs only when there is an impairment of vision. However, the relation between impairment of function and minimal ophthalmoscopic detectable lesions is not yet clearly established. To account for the inherent uncertainties, the following safety factors have been introduced:

- a. Calculated retinal exposures, $Q_r(\text{CALC})$, are arbitrarily multiplied by a factor of two in an effort to allow for possible inadequacies in weapon data and the method of calculation. Thus $Q_r = 2Q_r(\text{CALC})$.
- b. Minimal burn threshold data, determined from experiments on rabbits, are converted to human sub-threshold values by decreasing the measured threshold values, $Q_r^T(\text{MEAS})$, by a factor of four. Thus, $Q_r^T = Q_r^T(\text{MEAS})/4$.

Briefly, Q_r is calculated as a function of the distance between the observer and the fireball taking into account weapon characteristics, atmospheric transmission, and properties of the eye. The allowable distance of nearest approach (safe separation distance) is then obtained by comparing values of Q_r to values of Q_r^T , also calculated as a function of the distance between observer and fireball. The safe separation distance, measured along the earth's surface, is the distance at which $Q_r = Q_r^T$.

Since Q_r is dependent on the total masses of air and water vapor in the path between detonation and observer, safe separation distances vary with both detonation altitude and observer (flight) altitude. Figure 9 illustrates the model used to take these geometrical factors into account in the results presented in Figures 13-116.

Figure 10 shows a plot of Q_r and Q_r^T vs. horizontal range. The point of intersection of these curves ($Q_r = Q_r^T$) defines the minimum allowable distance of approach for one particular burst and flight altitude combination. To generate an "envelope" curve such as shown in Figure 11, large numbers of Q_r and Q_r^T curves must be examined. This was done using a computer program and the results are contained in Figures 13-116. For distances inside the boundaries defined by these curves, there is the possibility of eye injury as a result of retinal burns. For distances outside the boundaries, no injury is predicted.

Flashblindness

Flashblindness envelopes are generated in much the same manner as are the retinal burn envelopes, i.e., a calculated exposure, E_r , is compared to an allowable exposure, E_r^A . However, in this case, the calculation of the exposure is somewhat more complicated than in the case for retinal burns. A brief description of the approach is given here with a detailed description appearing in Appendix B.

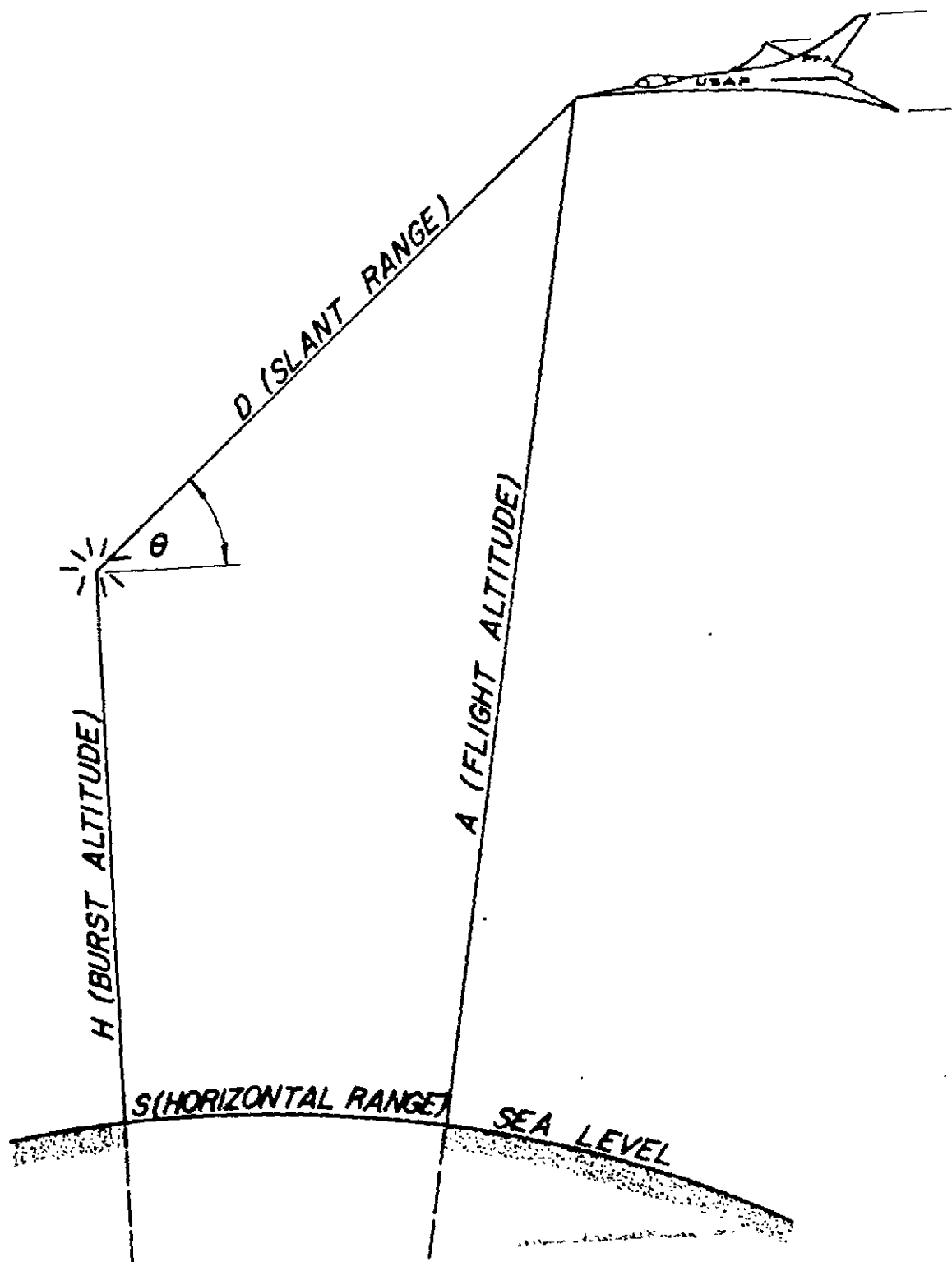


FIGURE 9. Model used for calculating transmission of the atmosphere

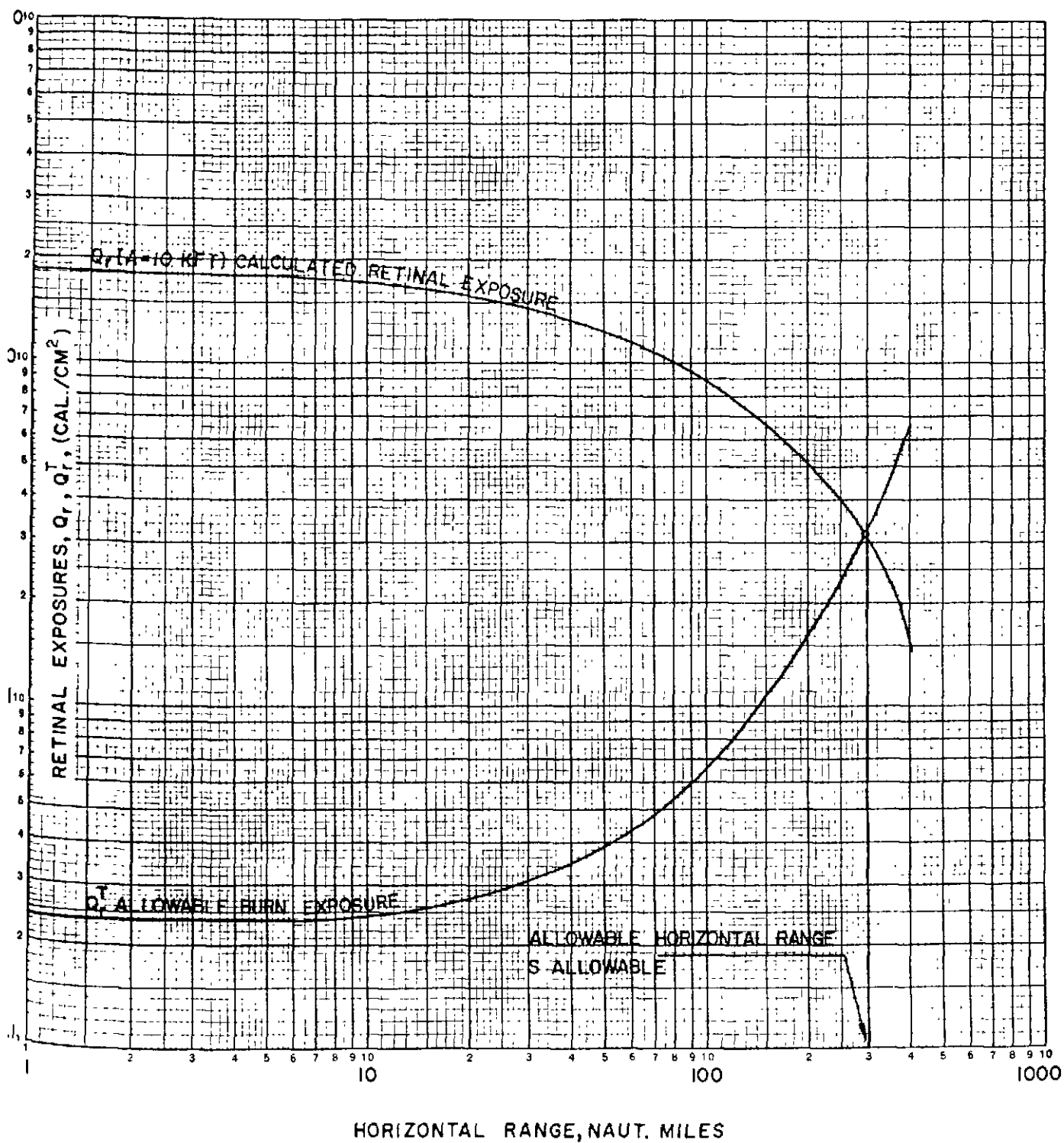
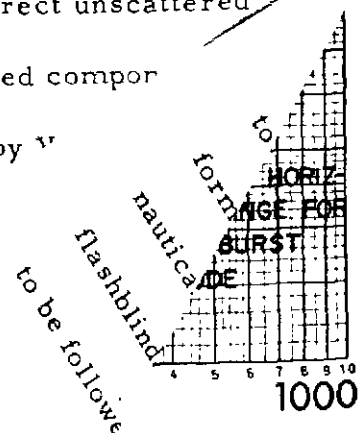


FIGURE 10. Threshold distance determination

If the image of the fireball falls directly on the fovea and the image is approximately the size of the macula (or larger), a significant period of flashblindness can result--even though no burn is produced. For this case, calculation of the exposure is accomplished exactly as for retinal burns except that the exposure is expressed in troland-seconds. However, if the fireball subtends an angle less than about three degrees (one millimeter image diameter) it is possible to "look around" the afterimage using the para-fovea area where acuity is still relatively high⁽¹⁰⁾. Thus, a very small afterimage in the macula may be annoying but it does not present a significant decrement in visual acuity. Accordingly, recovery time is computed for a foveal exposure from the direct (unscattered) radiation only when the image of the fireball is equal to or greater than one millimeter. When the image of the fireball is less than one millimeter, it is assumed that the limiting stimulus will be presented to the fovea by diffuse radiation that reaches the retina after being scattered from the air, clouds, ground or water, and by the clear media of the eye itself. Calculation of this component of the luminous energy is in principal much more complex than is the calculation of the direct unscattered radiation that makes up the image. Estimation of the scattered component is accomplished through an adaptation of the method described by "Nautica". Exposures calculated in this way are compared with threshold values (for a specified recovery time) determined in laboratory tests. As before, the condition $E_r = E_r^A$ defines the safe distance.



RETINAL BURN

DAY _____ MISSION _____

YIELD. 2 KT

FILTER: NONE

SYMBOL

A

B

C

D

BURST ALTITUDE (Kilofeet)

50

100

—

—

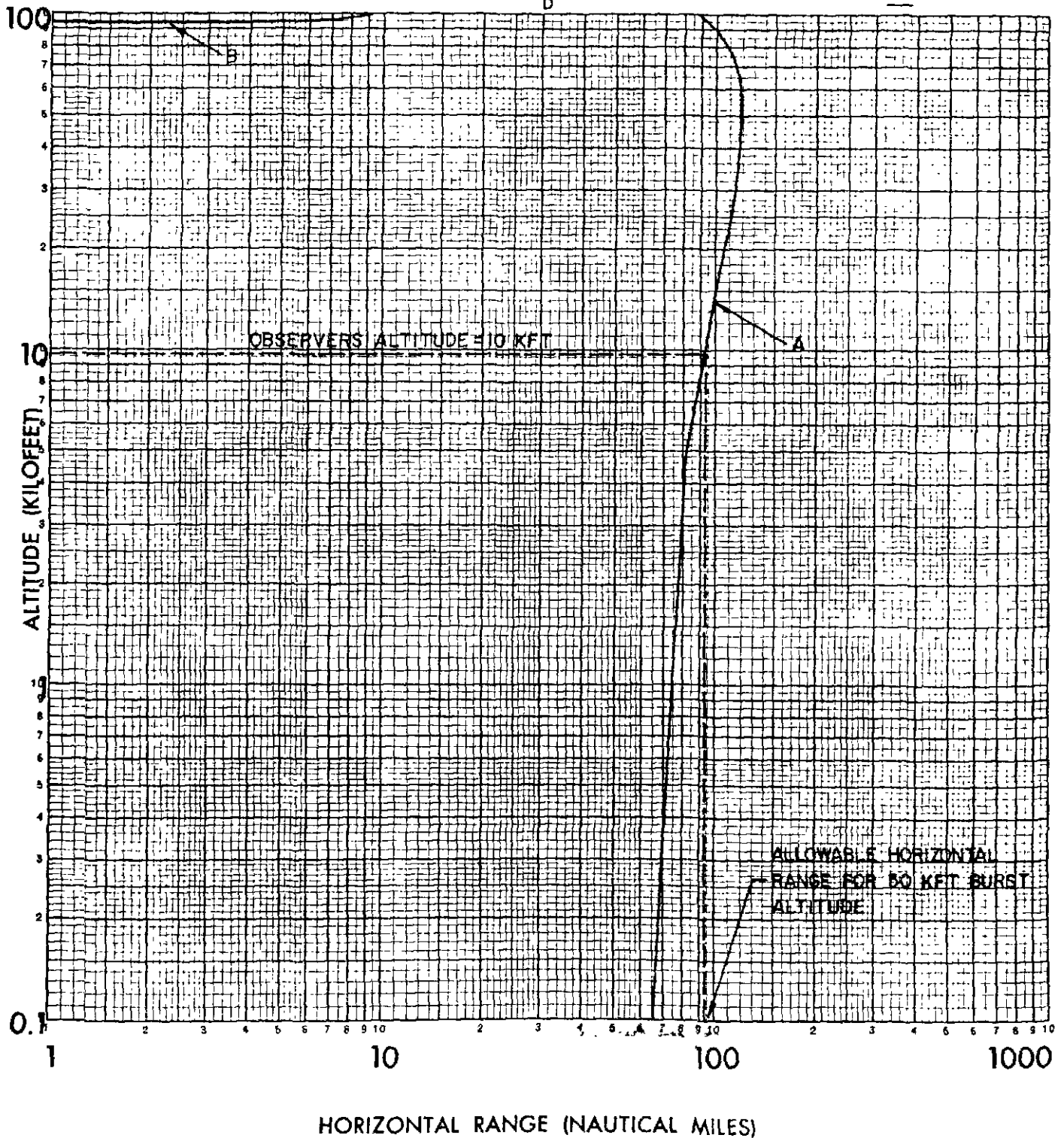


FIGURE 11. Typical retinal burn safe separation envelope.

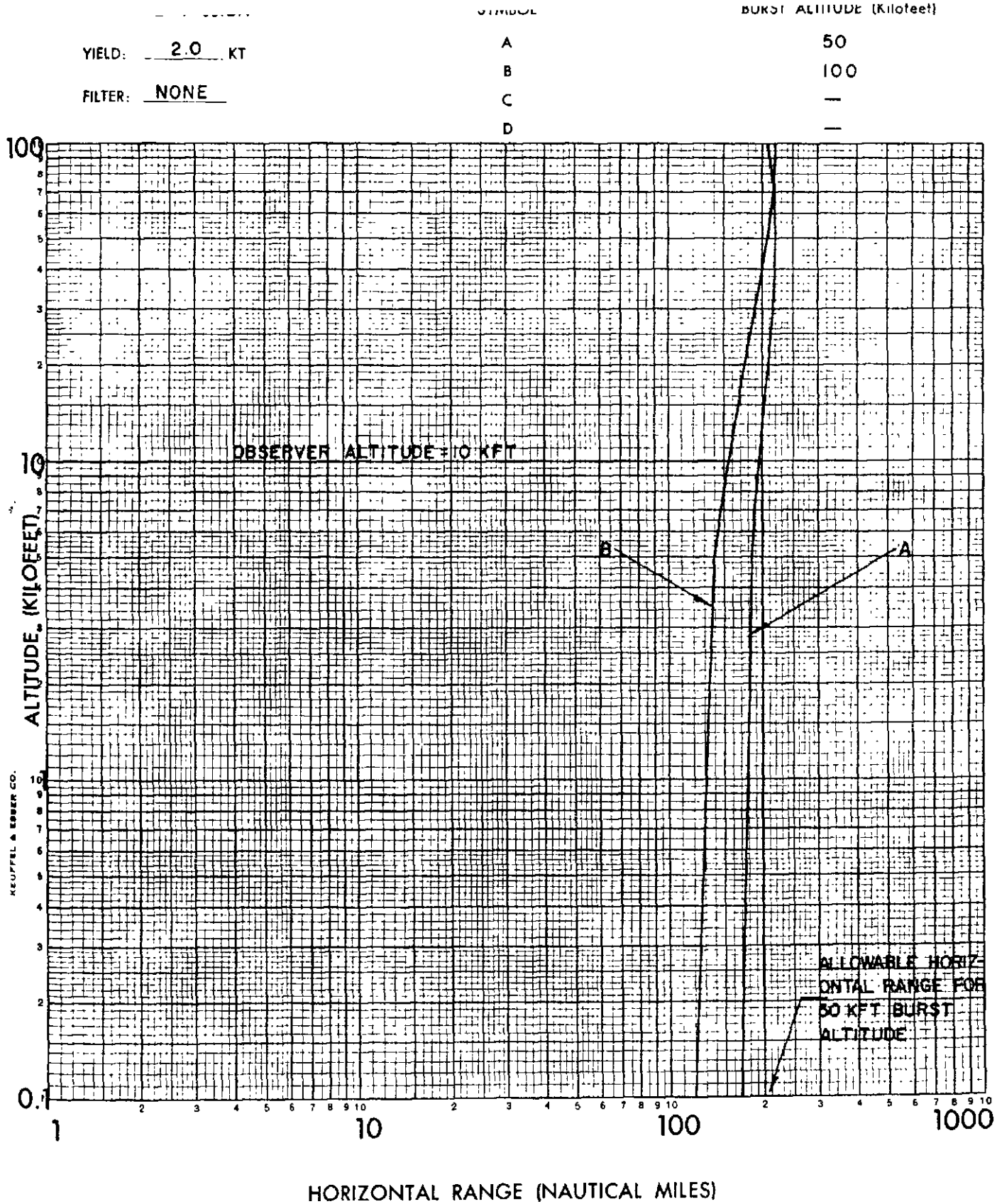


FIGURE 12. Typical flashblindness safe separation envelope.

According to the procedures discussed above, the curves presented in Figures 13-116, describe distances at which visual acuity will return to 20/120 at the center of the fovea, or at 1-1/2 degrees from the center of the fovea, within 10 seconds under typical cockpit lighting conditions. Figure 12 shows a typical flashblindness envelope.

V. MISSION PLANNING

The charts (Figures 13-116) included in this section can be used to assess the retinal burn and flashblindness hazard in planning nuclear strike missions. It is assumed that, for planning purposes, the following are known:

- 1) Weapon yield
- 2) Detonation altitude
- 3) Observer altitude
- 4) Day or night detonation

With the charts and this information, allowable separation distances or "danger-zones" can be established. The term "danger-zone" does not mean prohibited zone, but merely that appropriate safety measures should be taken to insure aircrew eye safety while in the zone. Each of the curves has the same format, with altitude given in thousands of feet and horizontal range given in nautical miles. Figures 11 and 12 illustrate the use of the retinal burn and flashblindness charts in determining allowable separation distances. The steps to be followed in using a chart are outlined below:

- 1) Select the set of "day" or "night" curves for the weapon yield under consideration. Each curve applies to a particular burst altitude as noted in the legend. Identify the curve which represents the desired burst altitude.
- 2) Select the observer altitude on the ordinate and follow this altitude horizontally to its intersection with the envelope curve.
- 3) The abscissa of the point of intersection is then the allowable separation distance. This value can be used directly on a map, or the slant range can be calculated as follows:

$$\text{Slant Range (Naut. Miles)} = \left[(\text{Horiz. Range})^2 + \left(\frac{\text{Obs. Alt.} - \text{Burst Alt.}}{6.08} \right)^2 \right]^{1/2}$$

Where Horizontal Range is in nautical miles and both Observer Altitude and Burst Altitude are in kilofeet.

Safe separation envelopes have been calculated for detonations during daylight (with and without a 2% gold visor for protection) and for night detonations. The protection afforded by the gold visor is sufficient to eliminate the hazard of retinal burns for day exposures for all of the situations considered, therefore, no envelopes are presented for this combination of conditions.

It should be emphasized that the "safe separation" distances presented here pertain only to retinal burns or flashblindness and are specific to the exposure conditions assumed, e. g. 0.25 second or 0.45 second blink time, 2.5 mm or

6.5mm pupil diameter, etc. If an allowable distance for flashblindness is less than an allowable retinal burn distance, the conclusion is simply that retinal burns present the limiting approach distance insofar as these two phenomena are concerned. It may be that in some instances the blast, thermal, or radiation hazard extends to a greater distance than either the flashblindness or retinal burn hazard. In this case, the allowable approach distance is not determined by retinal burns or flashblindness.

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TO <i>SMSPP (Miss Reynolds)</i>		INITIALS	CIRCULATE		
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REMARKS <i>attched are three corrected pages to be inserted in the Quarterly Progress report on contract 41(609)-7900 for the period 31 March 66 thru 30 June 66.</i>					
FROM <i>EO Richey</i>		DATE			
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1. INTRODUCTION

This Quarterly Progress Report is submitted to describe activities in connection with Contract AF 41(609)-2900 which calls for the preparation of a Technical Report concerning the effects of nuclear flashes on vision.

2. WORK ACCOMPLISHED

During this report period, the following objectives have been accomplished:

1. Selection of mathematical model, calculation technique, and format charts for retinal burn curves.
2. Manual calculations for 1, 3, 100, 500 and 1000 KT bursts at several altitudes to serve as checks with experimentally determined burn data.
3. Generation of computer programs to calculate and plot all combinations of parameters envisioned for inclusion in the handbook.
4. Literature survey and initial work in selecting mathematical model and parameter values for flashblindness envelopes

Example Calculation

To illustrate the entire technique in generating a typical retinal burn envelope, the following is a sample calculation:

Mission: 100 KT weapon; burst altitude = 2.7 kilofeet, flight altitude = 10 kilofeet; night mission.

$$H = 2.7 \text{ kft}$$

$$A = 10.0 \text{ kft}$$

$$d_p = 6.5 \text{ mm}$$

$$W = 100 \text{ KT}$$

$$M = \frac{1.4 \times 10^{-3}}{1.34 \times 10^{-6}} \frac{[(2.7 - 10)^2 + S^2]^{1/2}}{|(2.7 - 10)|} \left[\exp[-0.041 \times 10] - \exp[-0.041 \times 2.7] \right]$$

$$M = 33.2 [53.4 + S^2]^{1/2}$$

similarly

$$W = 0.249 [53.4 + S^2]^{1/2}$$

so that

$$\tau_a = \exp[-0.00806 (53.4 + S^2)^{1/2}]$$

next

$$Q_r = \frac{(0.79)(0.33)(0.10)(1.00)(0.8)(1.0)(10^{12})}{(4\pi)(\frac{17}{6.5})^2 (6.5 \times 10^{-4})^2} \exp[-0.00806(53.4 + S^2)^{1/2}]$$

$$Q_r = 5.8 \exp \left[-0.00806 (53.4 + S^2)^{1/2} \right]$$

which is the relation used to plot a Q_r vs. S curve.

$$\begin{aligned} \text{Now } d_i &= \frac{F d_{fb}}{\left[53.4 + S^2 \right]^{1/2}} \\ &= \frac{(17)(6.5 \times 10^5)}{(3.048 \times 10^4) \left[53.4 + S^2 \right]^{1/2}} \text{ mm} \end{aligned}$$

$$\text{or } d_i = \frac{363}{\left[53.4 + S^2 \right]^{1/2}} \text{ mm}$$

From a plot of Q_r^T vs. d_i (Figure 5) and the above relation between d_i and S , it is possible to plot Q_r^T vs. S and determine the threshold horizontal range, S_{\min} , which, for this particular case is about 20 nautical miles.

The above procedure must now be repeated again and again to generate S_{\min} vs Altitude curves such as in Figure 8.

Correlation with Field Data

Table 2 compares values of minimum calculated threshold burn distances for rabbit retinas at night with experimental threshold data under the same conditions of burst and flight altitude and

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TEXAS DIVISION

8531 N. NEW BRAUNFELS AVENUE
SAN ANTONIO, TEXAS 78217
Tel.: 512 TA4-7373
TWX: 512-571-0939

27 September 1966

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

Subject: Quarterly Progress Report
Contract AF 41(609)-2900

Enclosed are three (3) copies of the Quarterly Progress Report for the subject Contract. This report covers the period from 1 July 1966 through 30 September 1966.

John A. Russell
Project Engineer

JAR/df

cc: DCRO-DDCC
DCRO-DDPE
AMSKR-1

Enclosures

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LIFE SCIENCES DIVISION

SAN ANTONIO, TEXAS


Progress Report No. 4

Period 1 July 1966 to 30 September 1966

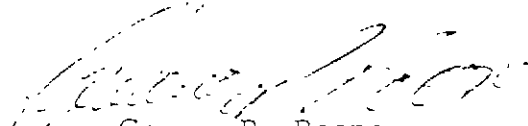
Contract: AF 41(609)-2900

NUCLEAR FLASH EYE EFFECTS TECHNICAL REPORT

PREPARED BY:


John A. Russell
Project Engineer

APPROVED BY:


George R. Boone
General Manager

1. INTRODUCTION

This Quarterly Progress Report is submitted to describe activities in connection with Contract AF 41(609)-2900 which calls for the preparation of a Technical Report concerning the effects of nuclear flashes on vision.

2. WORK ACCOMPLISHED

During this report period, the following objectives have been accomplished:

1. Development of computer programs to calculate and plot retinal burn and overpressure envelopes for various combinations of parameters.
2. Selection of a model for generation of flashblindness envelopes from data generated by the above retinal burn program.
3. Format design for the different envelopes.

Retinal Burn Envelope Techniques

The calculations for generation of retinal burn envelopes have been detailed in Quarterly Progress Report No. 3, and will not be repeated here. Sample curves from the computer program are shown in Appendix A, and are typical of those proposed for inclusion

in the handbook.

Overpressure Envelope Techniques

The relationship used to compute overpressure envelopes is taken from Reference 1, and is:

$$S = \left[\frac{0.0256 p^{0.83} W^{0.667}}{\Delta p^{1.48}} - (H-A)^2 \right]^{1/2}$$

where

S = Horizontal range, kilofeet

p = Atmospheric pressure at burst altitude, lb/ft²

W = yield, kilotons

Δp = maximum allowable overpressure, lb/in²

H = burst altitude, kilofeet

A = observer altitude, kilofeet

$\Delta p \approx 1.0 \text{ lb/in}^2$ for a century-series aircraft flying directly at the fireball, and 0.20 lb/in^2 for a transport aircraft broadside to the blast. The curves shown in Appendix B are for $\Delta p = 1.0 \text{ lb/in}^2$.

Flashblindness Envelope Technique

In Quarterly Progress Report No. 3, two different techniques for determining flashblindness thresholds were discussed - an "image

size model" and an "energy level model". Further investigation of the problem has shown that either technique by itself would be inadequate, and a model has been developed which will combine the more reasonable features of both. From Richey (2) and Miller (3), a retinal exposure of 0.01 cal/cm^2 will result in about a 5-second recovery time for a brightly-lighted target (131 mL). In addition, an image size of 1.0 mm on the fovea will reduce visual acuity to 20/40 - the minimum permissible value for aircrew members (4). From this information, it is possible to envision two critical situations which could occur in viewing a fireball:

(1) a large image of fairly high exposure within the image ($d_i \geq 1.0 \text{ mm}$, $Q_r \geq 0.01 \text{ cal/cm}^2$), and (2) a small image of extremely high exposure within the image ($d_i \ll 1.0$, but $Q_r \gg 0.01 \text{ cal/cm}^2$).

From the model illustrated in Figure 1, the extra-image retinal exposure, Q_B , is assumed to be a direct function of Q_r , the retinal exposure within the image, i. e., $Q_B = kQ_r$ where k is some constant, $0 < k \leq 1.0$. Probably, a value of $k = 0.1$ is not unreasonable, but further study will be required to define a meaningful value. For the purpose of illustration, a value of $k = 0.1$ is assumed here.

The proposed technique for generation of a flashblindness envelope

is to compare (for a particular burst situation) the horizontal range, S_d , which corresponds to $d_i = 1.0\text{mm}$, to the horizontal range, S_Q , for which $Q_r = 0.01 \text{ cal/cm}^2$. If $S_Q \leq S_d$, the envelope abscissa is defined by S_Q since exposures less than this give recovery times less than 5 seconds, regardless of image size. However, if $S_Q > S_d$, the situation of case (2) above may be encountered and the governing criterion would be the extra-image exposure, Q_B . The point at which $Q_B = 0.1 Q_r = 0.01 \text{ cal/cm}^2$ then defines the abscissa for the envelope.

For a graphical illustration of the process, consider Figure 2. In Figure 2 (a), one proceeds out along the Q_r curve until the curve drops to $Q_r = 0.01 \text{ cal/cm}^2$. Since values below this are of no consequence for flashblindness, the minimum horizontal range is at point (2), S_Q . (Note that S_d is not encountered until farther out along the Q_r curve.) In Figure 2 (b), one follows the Q_r curve until reaching the horizontal range S_d for which image diameter is 1mm. Beyond this point, we are not concerned with image size, and, therefore, drop to the $Q_B = 0.1 Q_r$ curve (pt (2) to pt (3)) and continue to pt (4) where $Q_B = 0.1 Q_r = 0.01 \text{ cal/cm}^2$, which defines the minimum horizontal range.

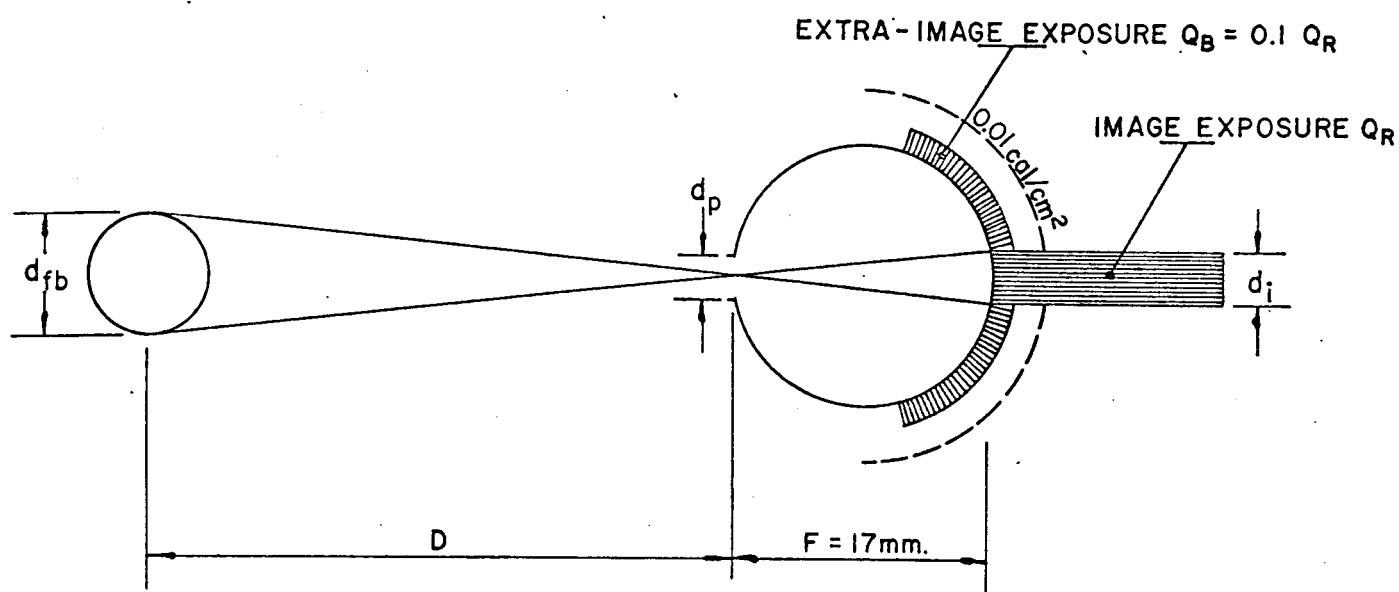
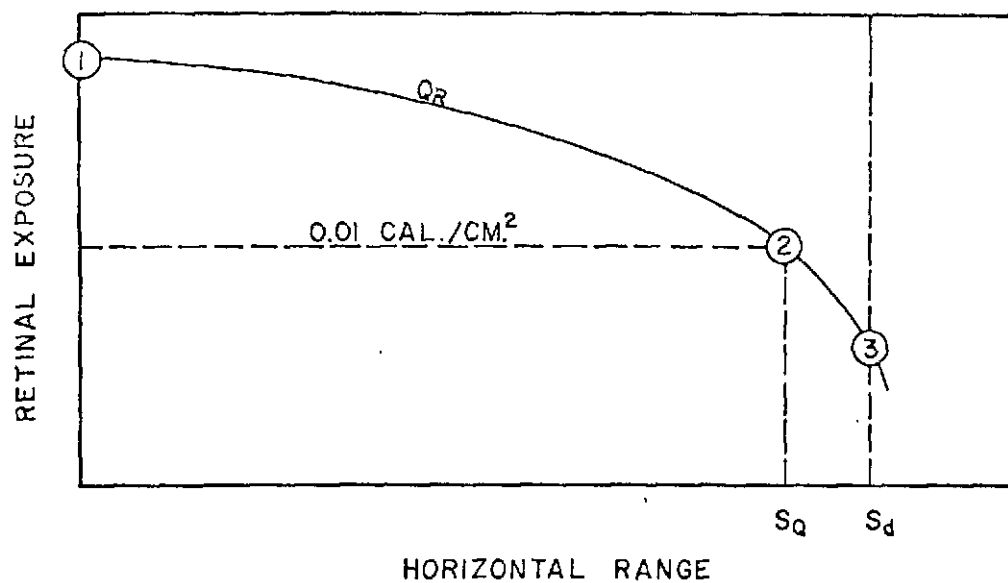
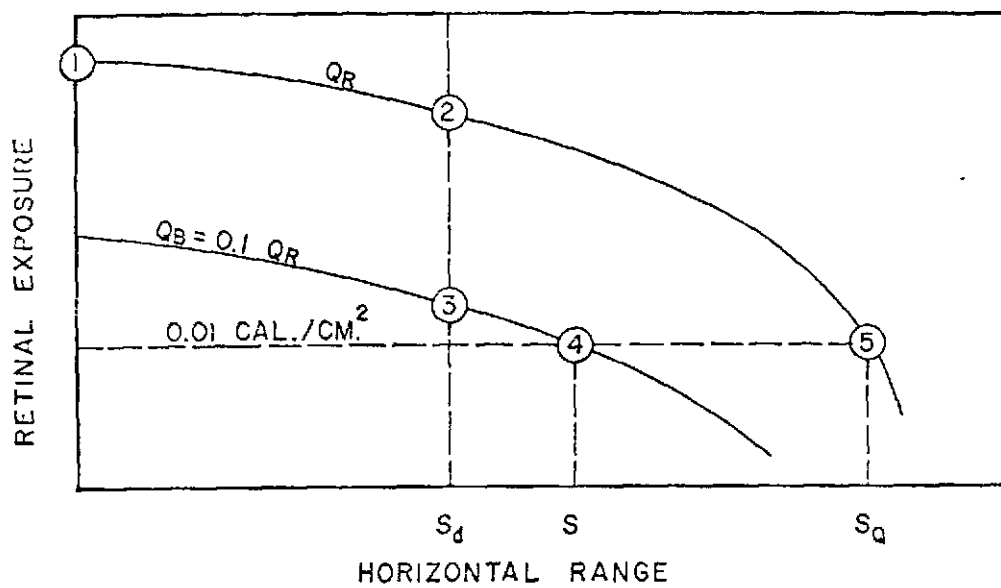


FIGURE 1. Flashblindness Model



(a)



(b)

FIGURE 2. Determination of Flashblindness Threshold Distances

The above technique will relate flashblindness criteria to the calculations used in the approximation model for retinal burns and will thus provide a common basis for generation of both types of envelopes.

3. FUTURE ACTIVITIES

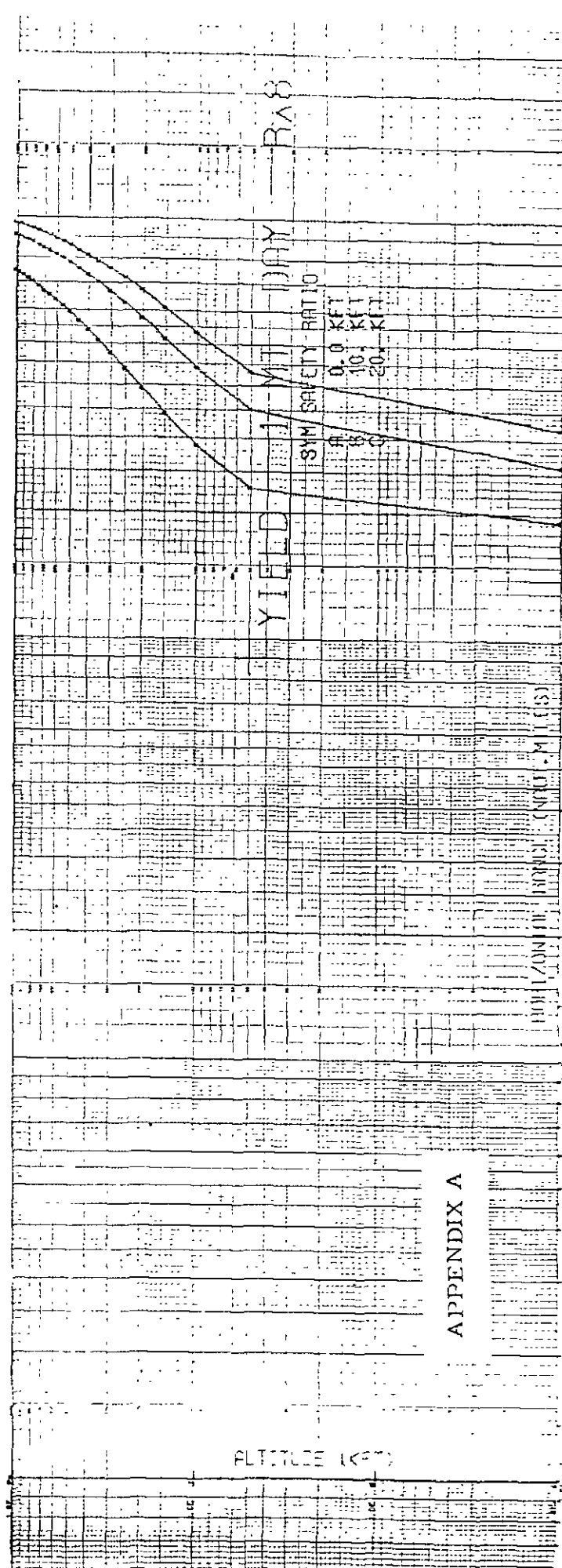
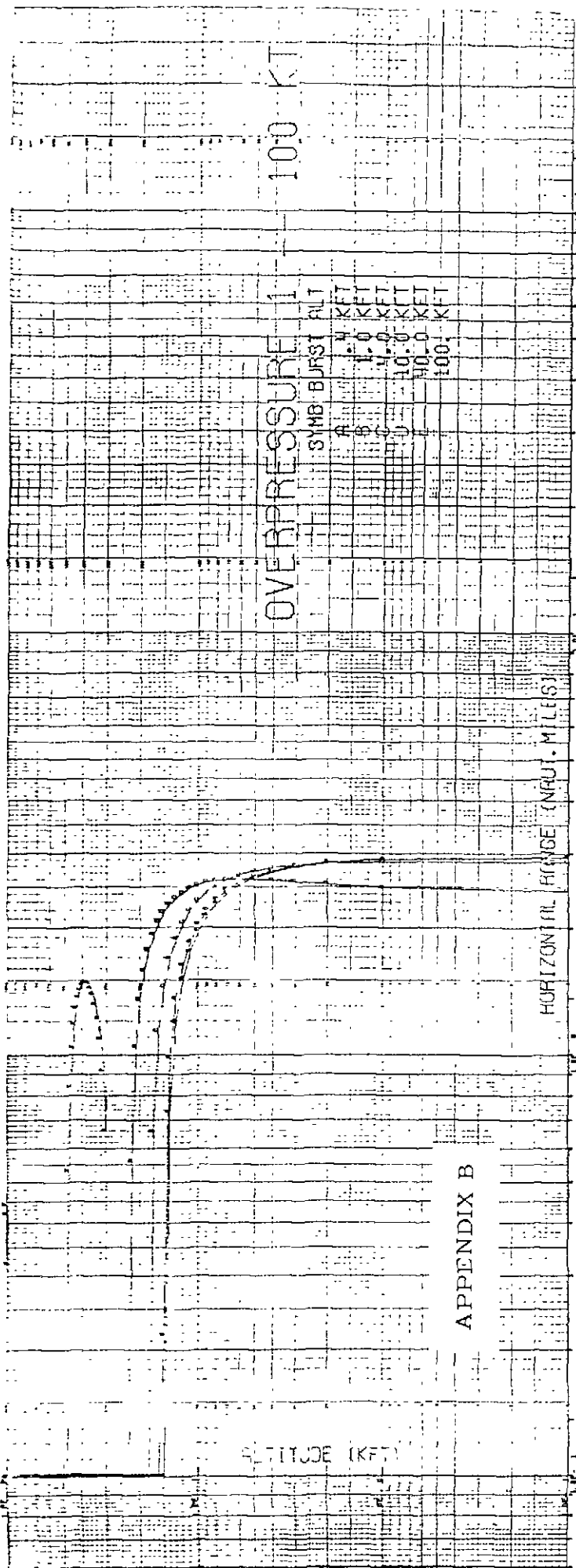
Effort in the final quarter of this project will be devoted to generation of all types of curves to be included in the handbook as well as writing and organizing the handbook proper (see Quarterly Progress Report No. 1 for outline).

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3. Miller, N. D.: Visual recovery from high intensity flashes. Annual Phase Report, USAF Contract AF 41(609)-2426, July 1965.
4. Personal communication from E. O. Richey to R. G. Allen, July 1966.

APPENDIX A - BURN CURVES

APPENDIX B - OVERPRESSURE CURVES



TECHNOLOGY
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TEXAS DIVISION

8531 N. NEW BRAUNFELS AVENUE
SAN ANTONIO, TEXAS 78217

Tel.: 512 TA4-7373


TWX: 612-571-0939

24 August 1966

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

Subject: Quarterly Progress Report
Contract AF 41(609)-2900

Enclosed are three copies of the Quarterly Progress Report for the subject Contract. This report covers the period from 31 March 1966 through 30 June 1966.


John A. Russell
Senior Research Engineer

JAR/df

cc: RCH BAC-30
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TECHNOLOGY INCORPORATED

LIFE SCIENCES DIVISION


SAN ANTONIO, TEXAS

Progress Report No. 3
Period 31 March 1966 to 30 June 1966


Contract: AF 41(609)-2900

NUCLEAR FLASH EYE EFFECTS TECHNICAL REPORT

PREPARED BY:


John A. Russell
Senior Research Engineer

APPROVED BY:


George R. Boone
General Manager
Life Sciences Division

1. INTRODUCTION

This Quarterly Progress Report is submitted to describe activities in connection with Contract AF 41(609)-2900 which calls for the preparation of a Technical Report concerning the effects of nuclear flashes on vision.

2. WORK ACCOMPLISHED

During this report period, the following objectives have been accomplished:

1. Selection of mathematical model, calculation technique, and format charts for retinal burn curves.
2. Manual calculations for 1, 3, 100, 500 and 1000 KT bursts at several altitudes to serve as checks with experimentally determined burn data obtained during Project Dominic.
3. Generation of computer programs to calculate and plot all combinations of parameters envisioned for inclusion in the handbook.
4. Literature survey and initial work in selecting mathematical model and parameter values for flashblindness envelopes

similar to burn envelopes.

5. Initial computer calculations of overpressure and flashblindness envelopes for a 100 KT weapon.

Retinal Burn Envelope Technique

- A. Flat-Earth Model - The method chosen for generation of retinal burn threshold envelopes is based largely on the work of Richey (1) and Allen (2). While the final data generated for use in the handbook will be based upon a "curved-earth" model (wherein the curvature of the earth's surface is accounted for in cases where it becomes significant), a "flat-earth" model has been employed to make preliminary calculations to check the selected technique against known experimental fact. The "flat-earth" model is illustrated in Figure 1. Geometric considerations are based upon a simple four-sided figure wherein an aircraft (or observer) is assumed to be at an altitude A above the earth's surface when a nuclear detonation occurs at an altitude H . Slant range from burst to aircraft is D , and Horizontal range (projection of D on the earth's surface) is S . From elementary trigonometry, the

elevation angle, Θ is

$$\Theta = \csc^{-1} \left[\frac{D}{H-A} \right]$$

where

$$D = \left[(H-A)^2 + S^2 \right]^{1/2}$$

or

$$\Theta = \csc^{-1} \frac{\left[(H-A)^2 + S^2 \right]^{1/2}}{(H-A)}$$

- B. Thin Lens Eye Model - The model used for calculation of image diameters produced on the retina is shown in Figure 2. While this system assumes that the eye behaves in a manner identical to the classical "thin lens", i.e.,

$$\frac{d_i}{d_{fb}} = \frac{F}{D}$$

or

$$d_i = \frac{F d_{fb}}{D}$$

where

d_i = image diameter, mm

F = focal length of eye (17 mm for human eye)

d_{fb} = fireball diameter, mm

D = slant range, mm.

it has been demonstrated that this simplification provides adequate accuracy for calculation of burn threshold distances.

C. Calculated Retinal Exposure - The equation

to calculate retinal exposure of the eye viewing a fireball is

$$Q_R = \frac{10^{12} a p k W T_e T_a T_x}{4\pi f^2 d_{fb}^2} \quad (\text{cal/cm}^2)$$

where

$a = 0.79$ = Fraction of the thermal energy radiated
which is located in the spectral region
effective in producing retinal damage
($350\text{m}\mu < E < 1500\text{m}\mu$ assuming a 5800°K
black-body radiator)

$p = 1/3$ = Fraction of total weapon yield converted to
thermal energy (low-altitude detonations)

k = Fraction of thermal energy released during
time t

W = Yield of the weapon in kilotons

$T_e = 0.8$ = Average transmission of clear media of the
eye (assumed 5800° black-body spectrum)

T_a = Average transmission of the atmosphere

T_x = Average transmission of any material between
the eye and the detonation (i. e., aircraft
canopy, sun glasses, filters)

$f = \frac{F}{d_p}$ = Ratio of the effective focal length of the eye-
lens system to the diameter of the pupil

d_{fb} = Average fireball diameter in centimeters
during exposure time t

D. Calculated Fireball Radius

Figure 3 shows the relation between scaled fireball radius

$$r_{fb}(s) = \frac{r_{fb}}{r_{fb}(t_{max})} \text{ and scaled time } t_s = \frac{t_B}{t_{max}} \text{ where}$$

r_{fb} = fireball radius, feet

$$r_{fb}(t_{max}) = 180 W^{2/5}, \text{ feet (3)}$$

t_B = blink reflex time, seconds

$$t_{max} = 0.032 W^{1/2}, \text{ seconds}$$

W = weapon yield, kilotons

Choosing $t_B = 0.25$ sec and $W = 100$ Kt:

$$r_{fb}(t_{max}) = 180 (100)^{2/5} = 1130 \text{ feet}$$

$$t_{max} = (0.032) (100)^{1/2} = 0.32 \text{ sec}$$

$$t_s = \left(\frac{0.25}{0.32} \right) = 0.78$$

From Figure 3 at $t_s = 0.78$, $r_{fb}(s) = 0.95$.

$$\text{So that } 0.95 = \frac{r_{fb}}{1130}$$

$$r_{fb} = (1130) (0.95) = 1072 \text{ feet}$$

The fireball diameter for a 100 Kt yield is then

$$\begin{aligned} d_{fb} &= 2r_{fb} = 2144 \text{ feet} \\ &= 6.5 \times 10^4 \text{ cm.} \end{aligned}$$

D. Calculated Thermal Energy Fraction

The term "k" in the above expression for retinal exposure is a time-dependent quantity which must be calculated for each selected yield. A generalized thermal pulse curve as shown in Figure 4 is used to determine the fraction of thermal

energy released in a time, t , as follows:

$$t W^{-1/2} = 0.025 \text{ for } t_B = 0.25 \text{ sec and } W = 100 \text{ KT}$$

So that from Figure 4, $k = 0.14$.

Several techniques based upon power, energy, and temperature characteristics of nuclear weapons in the wide spectrum of 10^{-2} to 10^5 KT yield are presently being investigated and compared in order to select the most realistic method for determining appropriate values of this parameter for each weapon.

F. Atmospheric Attenuation

It would be highly unrealistic to assume a so-called "average" atmospheric transmission, T_a , and assume that this value holds for a wide range of flight and burst altitudes.

Expressions have been derived which approximate T_a for given atmospheric situations, i. e., the moisture and air mass characteristics of the atmosphere along any slant range path from fireball to eyeball:

$$T_a(s) = \exp[-k_A^{\text{eff}} M] \exp[-k_W^{\text{eff}} W]$$

where

$$M = \frac{\rho_{Ao}}{q_A} \csc \Theta \left[\exp(-q_A A) - \exp(-q_A H) \right]$$

$$= \frac{\rho_{Ao}}{q_A} \frac{\left[(H-A)^2 + s^2 \right]^{1/2}}{(H-A)} \left[\exp(-q_A A) - \exp(-q_A H) \right]$$

and

$$W = \frac{\rho_{wo}}{q_w} \frac{\left[(H-A)^2 + s^2 \right]^{1/2}}{(H-A)} \left[\exp(-q_w A) - \exp(-q_w H) \right]$$

$$k_A^{\text{eff}} = \text{effective narrow-beam attenuation coefficient for air}$$

$$= 6.218 \times 10^{-5} \text{ (cm}^2/\text{gm)}$$

$$k_w^{\text{eff}} = \text{effective narrow-beam scattering coefficient for}$$

$$\text{airborne moisture}$$

$$= 2.409 \times 10^{-2} \text{ (cm}^2/\text{gm)}$$

$$q_A = \text{air lapse rate}$$

$$= 0.041 \text{ (kilofoot}^{-1}\text{)}$$

$$= 1.34 \times 10^{-6} \text{ (cm}^{-1}\text{)}$$

$$q_w = \text{moisture lapse rate}$$

$$= 0.1645 \text{ (kilofoot}^{-1}\text{)}$$

$$= 5.43 \times 10^{-6} \text{ (cm}^{-1}\text{)}$$

$$\rho_{Ao} = \text{sea level air density}$$

$$= 1.4 \times 10^{-3} \text{ (gm/cm}^3\text{) (ocean)}$$

$$\begin{aligned} p_{WO} &= \text{sea level moisture content} \\ &= 2.2 \times 10^{-5} \text{ (gm/cm}^3\text{) (ocean)} \end{aligned}$$

G. Threshold Retinal Exposure

The value of Q_r (above) which can be expected to produce minimal retinal burns on the human retina under a given set of circumstances is designated Q_r^T - the threshold retinal exposure. The technique used to obtain these values is based upon current experimental data obtained by producing actual burns on rabbit retinas. A plot of Q_r^T vs. exposure time for several image diameters is shown in Figure 5.

Experience tells us that a reasonable and conservative blink time for the human eye is 250 msec. Therefore, this value was chosen and will be used throughout the program as typical of average human eye response regardless of the stimulant source and environment (yield, day, night, etc.). If the family of curves shown in Figure 5 is sectioned at 250 msec, a plot of Q_r^T as a function of image diameter (which is in turn a function of fireball proximity) can be obtained. Figure 6 is such a curve. Thus a relationship between Q_r^T and D (or S) can be generated. From calculated Q_r vs. S and Q_r^T vs. S curves as shown in Figure 7, a simultaneous non-trivial numerical solution

of the two ($Q_r = Q_r^T$) will define the minimum horizontal range, S_{\min} , which would result in minimal retinal burns. The computer program will generate (numerically) families of such curves from which will be plotted final envelope-type curves of S_{\min} vs. altitude for a given mission. A typical curve is shown in Figure 8. From such figures, mission planners can quickly select (1) weapon, (2) fusing (burst altitude), (3) day or night flight, and determine safe observer (flight) proximity to the burst in terms of horizontal range and aircraft altitude.

Parameter Ranges

To encompass all anticipated USAF nuclear mission situations wherein an aircrew might be exposed to the hazards of retinal burn, flashblindness and critical overpressure, the parameters associated with the above model will be varied over ranges listed in Table 1. Naturally, certain combinations of yield and burst altitude are incompatible and will be eliminated from consideration so that the curves actually included in the handbook will represent only reasonable mission configurations. Close coordination with SAC, TAC, ADC, and other USAF agencies will be maintained in selecting practical combinations.

Example Calculation

To illustrate the entire technique in generating a typical retinal burn envelope, the following is a sample calculation:

Mission: 100 KT weapon; burst altitude = 2.7 kilofeet, flight altitude = 10 kilofeet; night mission.

$$H = 2.7 \text{ kft}$$

$$A = 10.0 \text{ kft}$$

$$d_p = 6.5 \text{ mm}$$

$$W = 100 \text{ KT}$$

$$M = \frac{1.4 \times 10^{-3}}{1.34 \times 10^{-6}} \cdot \frac{[(2.7 - 10)^2 + S^2]^{1/2}}{|(2.7 - 10)|} \left[\exp[-0.041 \times 10] - \exp[-0.041 \times 2.7] \right]$$

$$M = 33.2 [53.4 + S^2]^{1/2}$$

similarly

$$W = 0.249 [53.4 + S^2]^{1/2}$$

so that

$$T_a = \exp[-0.00716 (53.4 + S^2)^{1/2}]$$

next

$$Q_r = \frac{(0.79)(0.33)(0.10)(100)(0.8)(1.0)(10^{12})}{(4\pi)(\frac{17}{2.5})^2 (6.5 \times 10^5)^2} \exp[-0.0076(53.4 + S^2)^{1/2}]$$

$$Q_r = 25.6 \exp \left[-0.00716 (53.4 + S^2)^{1/2} \right]$$

which is the relation used to plot a Q_r vs. S curve.

$$\begin{aligned} \text{Now } d_i &= \frac{F d_{fb}}{\left[53.4 + S^2 \right]^{1/2}} \\ &= \frac{(17)(6.5 \times 10^5)}{\left[53.4 + S^2 \right]^{1/2}} \text{ mm} \end{aligned}$$

$$\text{or } d_i = \frac{21.5}{\left[53.4 + S^2 \right]} \text{ kft}$$

From a plot of Q_r^T vs. d_i (Figure 5) and the above relation between d_i and S , it is possible to plot Q_r^T vs. S and determine the threshold horizontal range, S_{\min} , which, for this particular case is about 20 nautical miles.

The above procedure must now be repeated again and again to generate S_{\min} vs Altitude curves such as in Figure 8.

Correlation with Field Data

Table 2 compares values of minimum calculated threshold burn distances for rabbit retinas at night with experimental threshold data under the same conditions of burst and flight altitude and

yield. As is evident, there is reasonably good agreement between calculated and measured data, indicating that the model described above serves as a reasonable approximation of actual conditions to be expected on nuclear missions--at least for the situation considered.

Retinal Burn Computer Program

A program has been written to compute retinal burn exclusion envelopes. This program is presently limited to low altitude detonations (probably on the order of 20,000 feet burst altitude) and observer altitudes from sea level to 100,000 feet. The properties of the atmosphere were obtained from the ARDC Standard Atmosphere 1959.

The fireball radius, fraction of yield, atmospheric transmission and allowable energy are contained as subroutines and therefore may be changed with a minimum of programming.

The preliminary program is listed in the Appendix.

Flashblindness Envelope Techniques

A. Image Size Model

A thorough study of the flashblindness problem has been conducted to gather data on how best to develop the mission

planning model. The flashblindness portion of the report poses more problems than the retinal burn portion because of the many different approaches possible in the solution of the problem.

Richey (1) examines the problem from two different points of view. He states that a pilot's ability to read his instruments should not be significantly affected by flashblindness when the afterimage has a diameter of less than 0.9 mm.

After sample calculations using the equation for image diameter,

$$D_i = \frac{d_{fb} F}{D},$$

it became apparent that for low intermediate

yield weapons, the distance from the fireball which gives a

$D_{ic} = 0.9$ mm is well within the limit at which chorioretinal

burns will occur. Figure 9 shows a plot of d_i vs D for one

particular mission. The flashblindness envelope would be

generated by finding the intersection of the 0.90 mm curve

with individual Q_r curves in a manner similar to that described

for Figure 7.

B. Energy Level Model

Another approach is to select a fixed retinal exposure of the order of 0.01 cal/cm^2 . This value is chosen as representative of the exposure required to produce a 5-second recovery time for a brightly lighted target (131 mL). If target luminance is reduced, then the retinal exposure for any selected recovery time must be reduced correspondingly. (1,4) Figure 10 is a plot similar to Figures 7 and 9 with a constant horizontal line representing 0.01 cal/cm^2 . The intersection of this Q_r^T line with individual Q_r curves for various flight altitudes generates another type of flashblindness envelope. However, at the distances involved, image diameter would be much less than 0.9 mm and the pilot would be able to read his instruments without much difficulty.

If scattering and reflection are taken into account, the entire field of vision would be exposed to a flash of light which would cause flashblindness of a short duration. However, the energy from reflection and scattering would not be greater than 0.01 cal/cm^2 unless a focusing effect could be achieved by a highly reflective surface.

A problem arises from the fact that for certain yields and burst heights, the ranges at which the $.01 \text{ cal/cm}^2$ level is reached, are in the vicinity of 300 N.M. It is possible that a logical decision will have to be made with regard to range and radiant exposure. At these ranges, the image size is approximately .03 mm which would not involve any problems with afterimages. The ideal solution to the problem would be to find some point at which the reflected and scattered light produces a radiant exposure of 0.01 cal/cm^2 . This point would have to be outside the retinal burn envelope and the image diameter must be 0.9 mm or less in size. If the image size is 0.9 mm or less, we can ignore the radiant exposure due to the image itself and concentrate on the radiant exposure due to reflections and scattering which would expose essentially the entire retina.

C. Future Activities

Effort during the next report period will be devoted to:

Development of a more accurate method for calculation of the term "k" (percent thermal radiation given off in blink time, t_B) both with respect to individual weapon characteristics and pulse variation with altitude.

Generation of a model for calculating fireball diameter which correlates more closely with experimental data.

Finalization of burn, flashblindness, and overpressure envelope format.

Coordination with appropriate USAF agencies to determine representative combinations of yield and burst altitude.

Determination and inclusion of meaningful safety factors for both Q_r and Q_r^T .

In addition, a major portion of the first draft of the text for the handbook will be written, including directions for use of the envelopes, derivation of the envelopes, and detailed instructions for interpolation between envelopes.

REFERENCES

1. Richey, Everett O. Prediction of eye safe separation distances. Presented at AGARD Symposium on Loss of Vision from High Intensity Light, Paris, France, March 1966.
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3. Glasstone, S. (ed). The effects of nuclear weapons. Revised Edition, 1962, U.S.G.P.O.
4. Miller, N. D. Visual recovery from high intensity flashes. Annual Phase Report, USAF Contract AF 41(609)-2426, July 1965.

Flat-Earth Model

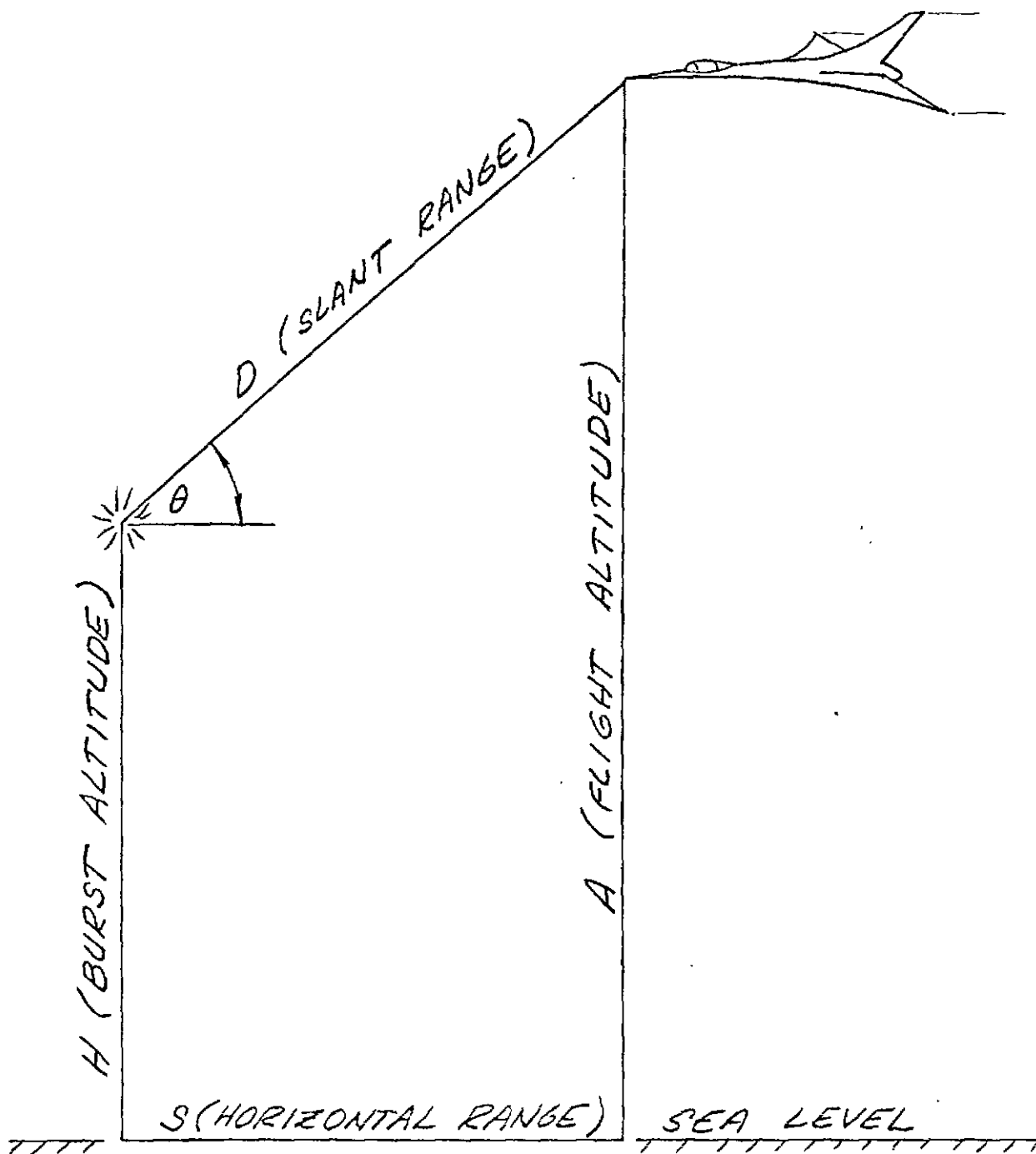


Figure 1

Thin Lens Model

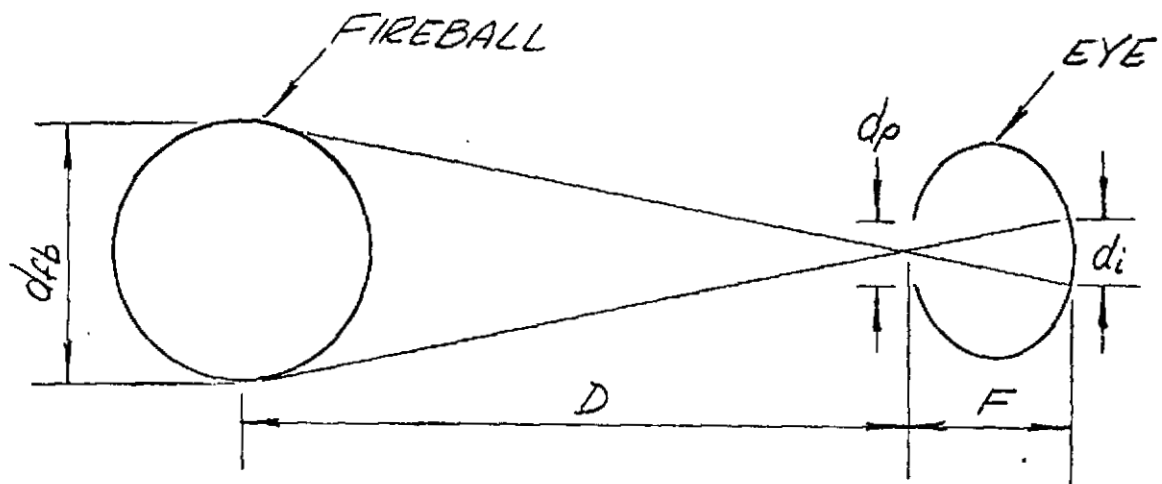
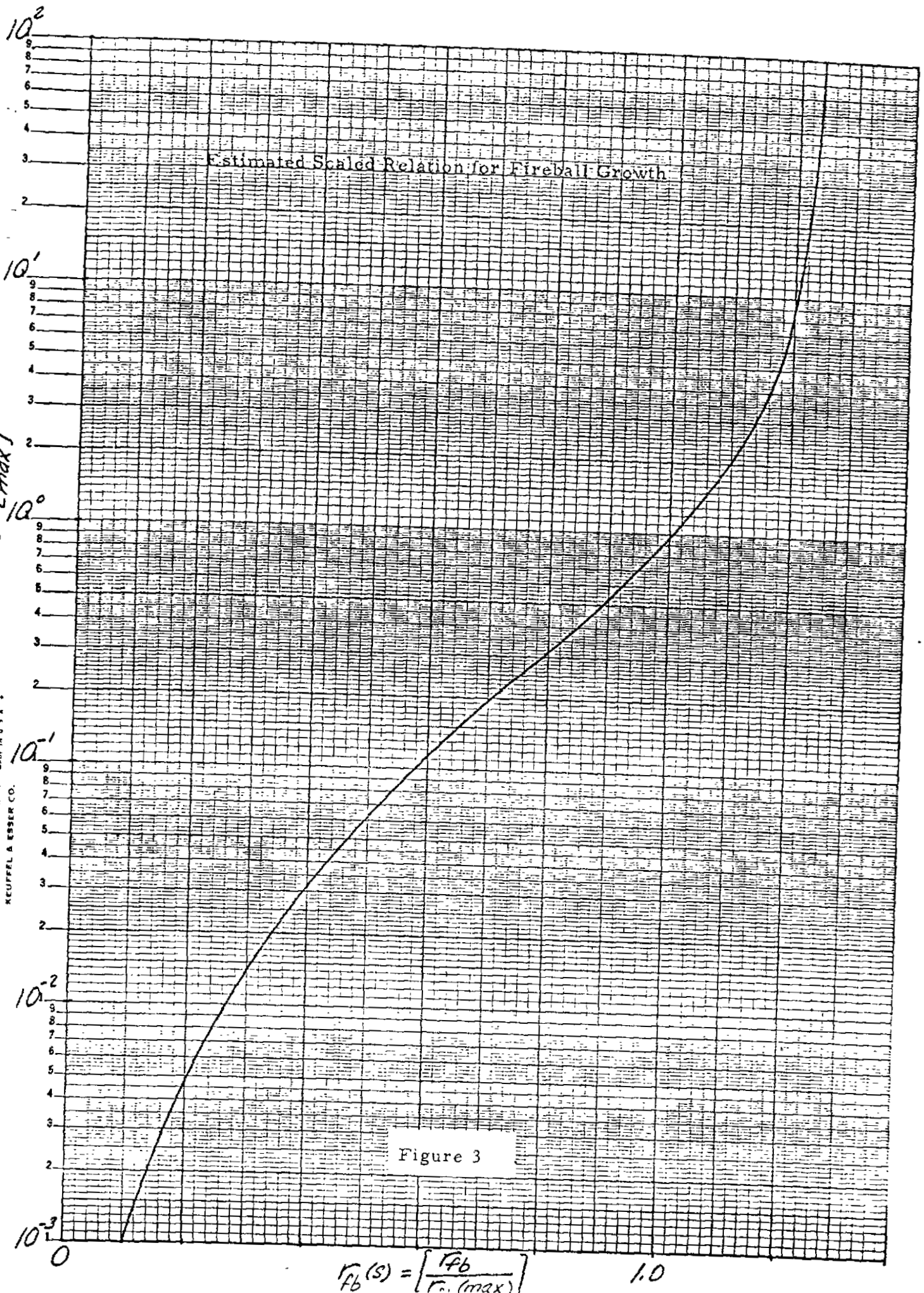


Figure 2

4G 6212
 SEMI LOGARITHMIC
 CYCLES X 75 DIVISIONS
 KEUFFEL & ESSER CO.
 MADE IN U.S.A.

$L_s \left(\frac{1}{t_{max}} \right)$



Generalized Thermal Pulse Characteristics

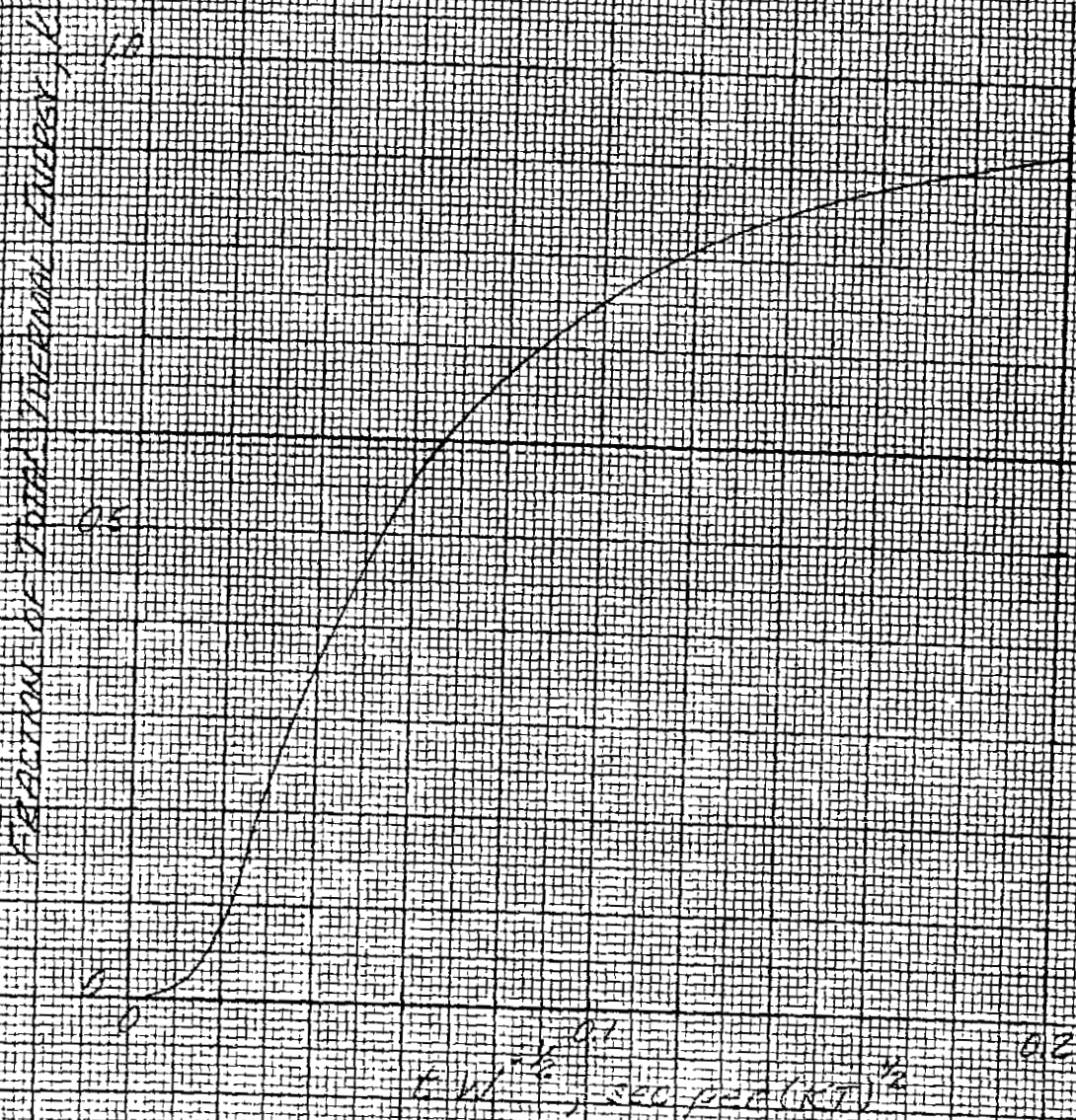
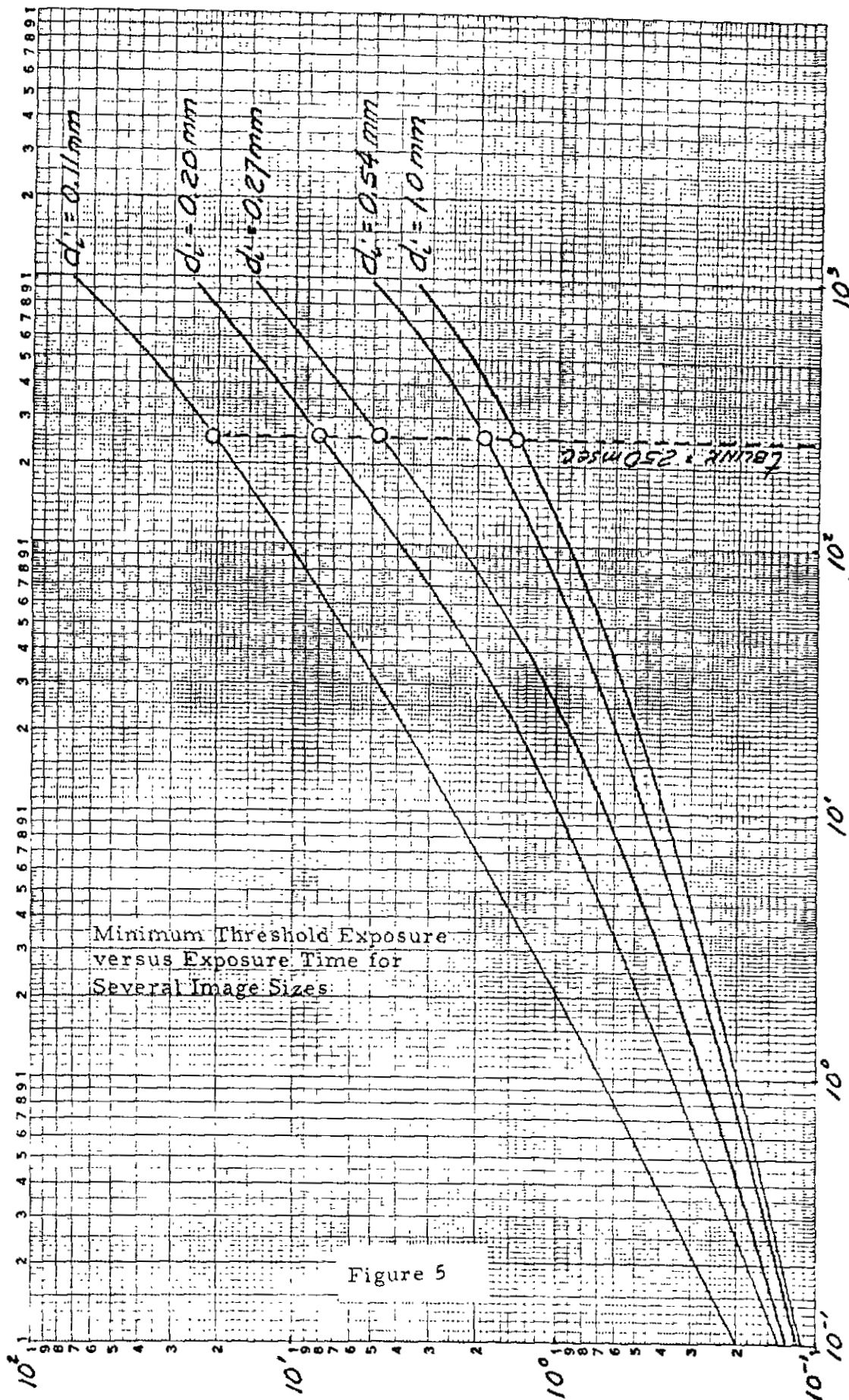


Figure 4

1 THRESHOLD RETINAL EXPOSURE, Q_T , cal per cm^2



EXPOSURE TIME, milliseconds

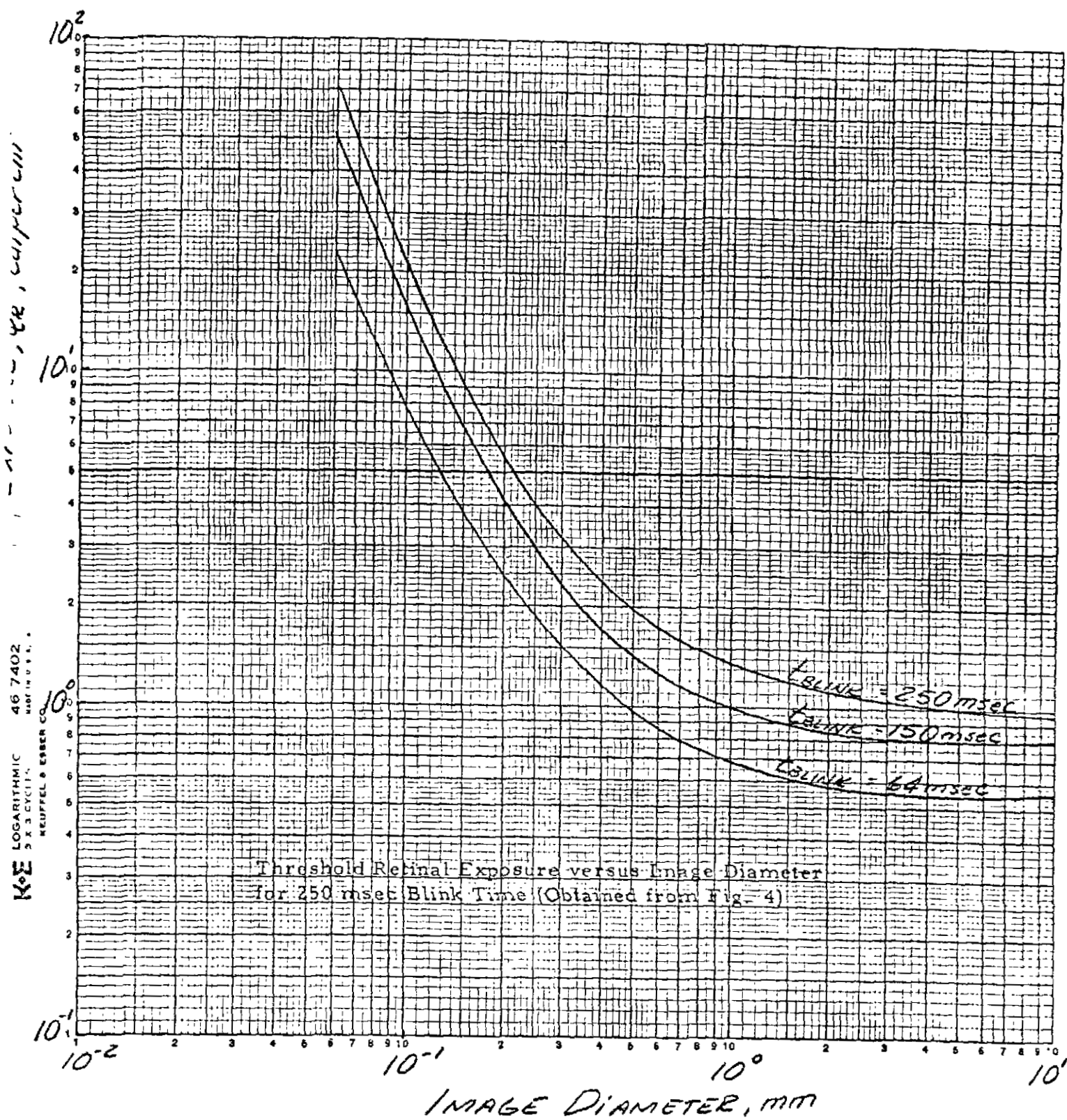
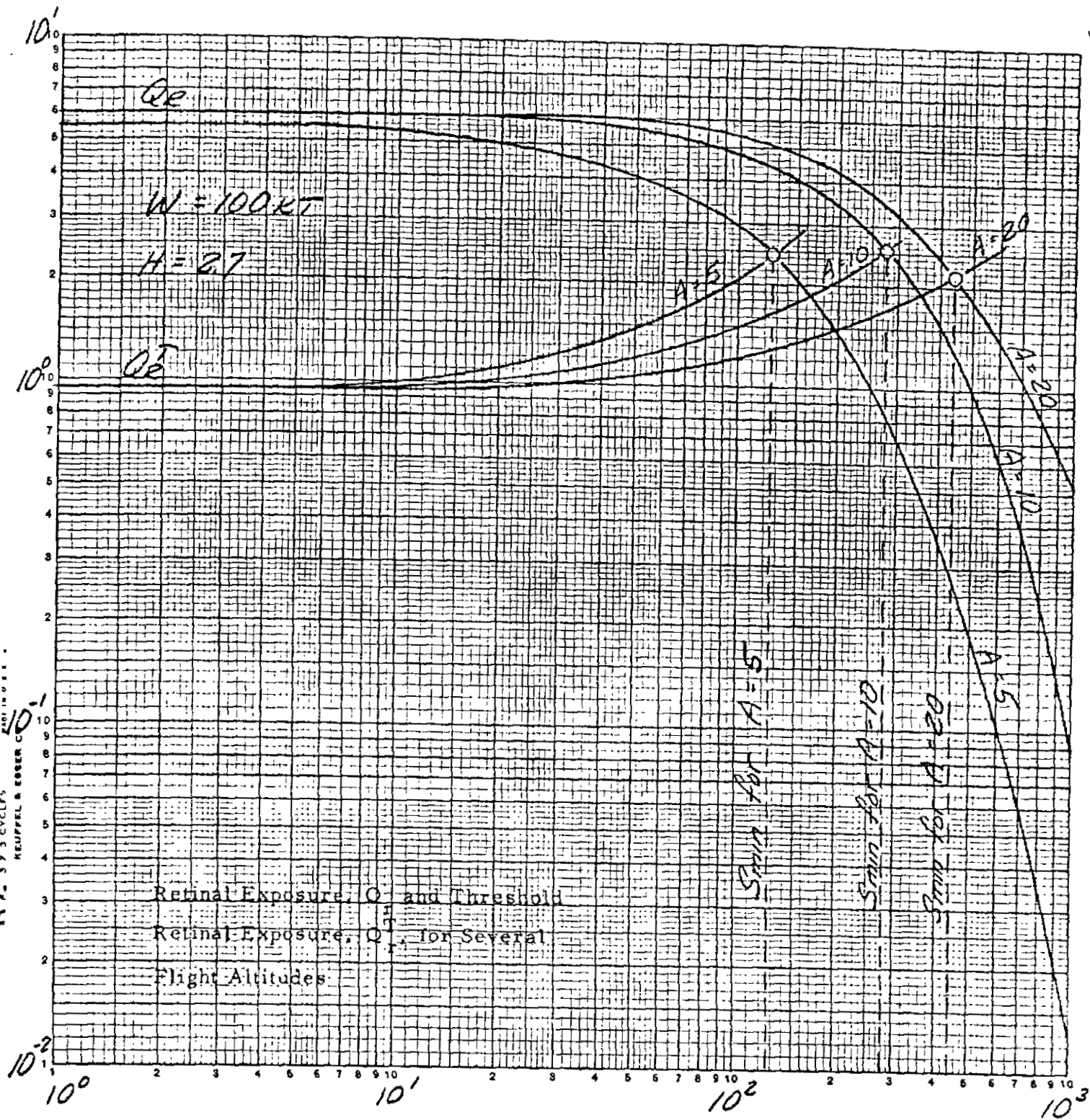
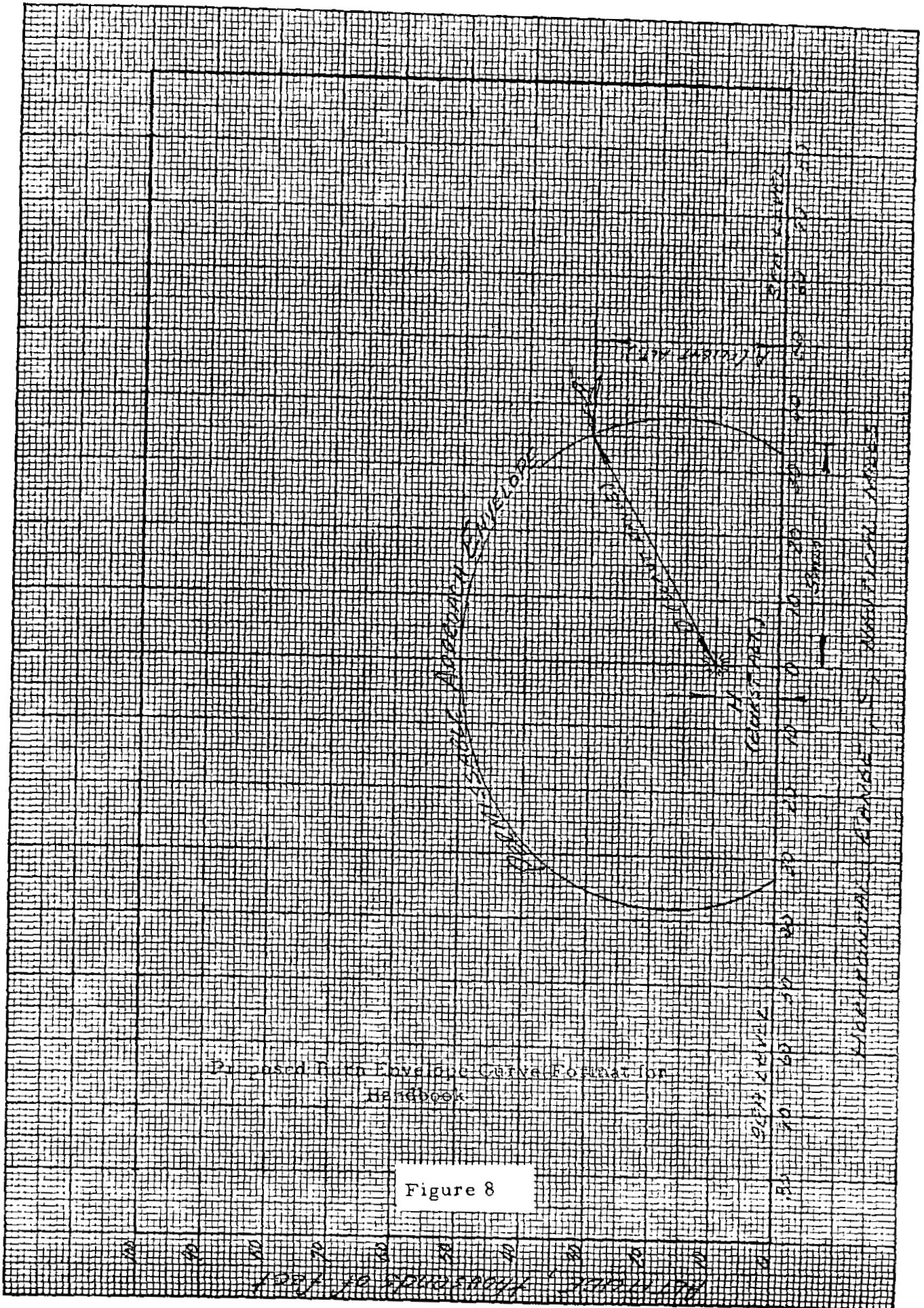


Figure 6



HORIZONTAL RANGE, S , KILOFEET

Figure 7



Proposed Parabolic Envelope Curve Formation Handbook

Figure 8

TABLE 1

Parameter Ranges for Burn and Flashblindness Envelope Generation

<u>Parameter</u>	<u>Range</u>
a	0.79 (constant)
p	0.33 to 0.67 (altitude-dependent)
k	0.001 to 0.60 (yield-dependent)
W	10^{-2} to 10^4 KT
T_e	0.80 (constant)
T_x	1.00 (constant)
f	2.68 (night); 6.8 (day)
H	0 to 1×10^5 feet
A	0 to 1×10^5 feet

TABLE 2

Comparison of Calculated Threshold Distances and Measured Distances
at which Retinal Burns Occurred for Rabbits at Night

<u>Yield, KT</u>	<u>Horizontal Range, S_{min}, Naut. Mi</u>	
	<u>Calculated</u>	<u>Measured</u>
3	18	20
100	20	20
500	36	35
1000	40	45

APPENDIX

Eye Safe Program

```

JOB      1A8NEZ0740CCWACO
DUMP     C,0,37777
DUMP     A,1000,37777
DUMP     F,1000,37777
IBIT     46
ABS      ALTAC  MAGTAPE,LIB
I        EYE SAFE
SUBROUTINE AIR(H,P,T,D) $
HKM=H*3.048E-4 $
IF(HKM) GT (25.),GO TO 20 $
IF(HKM) GT (11.),GO TO 10 $
T=288.16-6.5*HKM $
P=1033.2*(T/288.16)**5.2561 $
D=1.225E-3*(T/288.16)**4.2561 $
GO TO 30 $
10      T=216.66 $
C=EXPF(0.15769*(11.-HKM)) $
P=C*231.47 $
D=C*3.648E-4 $
GO TO 30 $
20      T=216.66+3.*(HKM-25.) $
P=25.772*(216.66/T)**11.3882 $
D=4.0639E-5*(216.66/T)**12.3882 $
30      T=T/288.16 $
P=P/1033.2 $
D=D/1.225E-3 $
RETURN $
END $
SUBROUTINE TRANS(A,HB,HR,PHB,DHB,AK,WK,DWO,WL,T) $
IF(HB) E (0.0),HB=1.0 $
IF(ABSF(1.-A/HB)) LTE (.001),AM=.037338*HR*DHB*WM=DWO*30.48*HR*
EXP(-WL*HB*0.001)*GO TO 10 $
CALL AIR(A,PA,TA,DA) $
SEC=SQRTF((A-HB)*(A-HB)+HR*HR)/(A-HB) $
AM=(PHB-PA)*SEC*1033.2 $
WM=30480.*DWO*SEC*(EXPF(-WL*HB/1000.)-EXPF(-WL*A/1000.))/WL $
10      T=EXPF(-AK*AM-WK*WM) $
RETURN $
END $
1000     FORMAT(8F10.0) $
1100     FORMAT(10A8) $
1200     FORMAT(7F10.0,2F5.0) $
1300     FORMAT(1H1) $
1400     FORMAT(//////////42X,35HNO RETINAL BURN ENVELOPE EXISTS FOR/
42X,16HTHIS SITUATION -//
42X,16HYIELD = ,E11.4/
42X,16HBURST HEIGHT = ,E11.4/
42X,16HPERCENT YIELD = ,E11.4/
42X,16HBLINK TIME = ,E11.4,7H DURING,A7,7HMISSION/
42X,16HQA FACTOR = ,E11.4/
42X,16HOR FACTOR = ,E11.4) $
1500     FORMAT(/40X,7HW = E11.4,4X,7HAK = E11.4/
40X,7HHB = E11.4,4X,7HWK = E11.4/
40X,7HDFB = E11.4,4X,7HDWO = E11.4/
40X,7HPERY = E11.4,4X,7HWL = E11.4/
40X,7HTB = E11.4,4X,7HTX = E11.4/
40X,7HTS = E11.4,4X,7HTE = E11.4/
40X,7HTSF = E11.4,4X,7HABAR = E11.4/
40X,7HF = E11.4,4X,7HP = E11.4/
40X,7HFL = E11.4,4X,7HFQA = E11.4) $
1600     FORMAT(35X,33HCONDITION AT MINIMUM ALTITUDE OF E11.4,5H FEET/

```

```

        61X,7HQA      = E11.4/
        61X,7HQREC    = E11.4/
        61X,7HDIM1    = E11.4) $
1700    FORMAT(35X,33HCONDITION AT MAXIMUM ALTITUDE OF E11.4,5H FEET/
        61X,7HQA      = E11.4/
        61X,7HQREC    = E11.4/
        61X,7HDIM2    = E11.4) $
1800    FORMAT(/35X,21HLET DELTA ALTITUDE = E11.4,5H FEET/////19X,
75HALTITUDE      H RANGE      H RANGE      Q ALLOWABLE  Q RECEIVE
D  IMAGE DIAM/21X,4HFEET,7X,6HN MILE,9X,3H FT,37X,2HMM) $
1900    FORMAT(18X,6(E11.4,2X)) $
        DIMENSION XAXIS(50),YAXIS(50),TITLE(10) $
        TABLEDEF FB(2,11) $
        NOPTS=0 $
        READ 1000,AK,WK,DWO,WL,TX,TE,ABAR,P $
TITL    READ 1100,(TITLE(I),I=1,10) $      THIS TITLE WILL APPEAR ON GRAPH
        IF(TITLE(1)) E (FINISH),GO TO EXIT $
        CALL AMGNPLT(XAXIS,YAXIS,NOPTS,+1,0,TITLE) $ INITIALIZE GRAPH
        CALL AMSETLM(XMAX,XMIN,YMAX,YMIN) $      SCALE THE GRAPH
CARD    READ 1200,W,PERY,HB,TB,TS,F,FL,FQA,FQR $      DATA CARD 1 CURVE
        IF(W) GT (0.0),GO TO CURVE $      IS CARD BLANK
        CALL AMWRAP $      WRAP UP THIS GRAPH
        GO TO TITL $
CURVE    PRINT 1300 $      INITIALIZE PAGE
        CALL AIR(HB,PHB,THB,DHB) $
        WSCL=0.032*(DHB*W)**0.5 $
        IF(TB) E (0.0),TB=(TS-0.0025)*WSCL'GO TO 10 $
        IF(TS) E (0.0),TS=0.0025+TB/WSCL'GO TO 10 $
        IF(TB) GT ((TS-.0025)*WSCL),TB=(TS-.0025)*WSCL'GO TO 10 $
        TS=.0025+TB/WSCL $
10      TSF=.032*TS $
        IF(TS) GTE (FB(1,11)),DF=FB(2,11)'GO TO 40 $
        IF(TS) LT (FB(1,11)),I=2'GO TO 30 $
        DO 20 I=2,11 $
        IF(TS) LT (FB(1,I)),GO TO 30 $
20      CONTINUE $
30      DF=FB(2,I-1)+LOGF(TS/FB(1,I-1))*(FB(2,I)-FB(2,I-1))/
        LOGF(FB(1,I)/FB(1,I-1)) $
40      DFB=360.0*DF $
        DFB=DFB*(W/DHB)**0.333 $      DIAMETER IN FEET
        DFBM=30.48*DFB $      DIAMETER IN CM
        QF=7.95775E10*ABAR*P*PERY*W*TE*TX/(F*F*DFBM*DFBM) $
        HR=1.0 $
        A=HB-1.0 $      CHECK TO INSURE THAT AN INTER-
        CALL TRANS(A,HB,HR,PHB,DHB,AK,WK,DWO,WL,T) $ SECTION DOES EXIST
        QREC=QF*T $
        QA=0.9163 $
        QRAT=(FQA*QA)/(FQR*QREC) $
        IF(QRAT) LT (1.0),GO TO TOWN $
        IF(F) GT (5.0),TITLE(1)=DAY $
        IF(F) LT (5.0),TITLE(1)=NIGHT $
        PRINT 1400,W,HB,PERY,TB,TITLE(1),FQA,FQR $
        GO TO CARD $
TOWN    HR=0.0 $
        QA=0.0 $
        QREC=0.0 $
        DIM1=0.0 $
        PRINT 1500,W,AK,HB,WK,DFB,DWO,PERY,WL,TB,TX,TS,TE,TSF,ABAR,F,P,
        FL,FQA $
        A=0.0 $
        IF(HB) LTE (1000.),AMIN=0.0'GO TO 80 $

```

```

A=HB $
DELT=10000. $
50 DELT=DELT/10. $
60 A=A-DELT $
IF(A) LTE (0.0),AMIN=0.0'GO TO 80 $ ARE WE AT SEA LEVEL
DIM1=FL*DFB/(HB-A) $
IF(DIM1) GT (FL),DIM1=FL $
QA=10.**((0.18*EXP(-2.14*LOG10(1.08*DIM1))-0.05) $
CALL TRANS(A,HB,HR,PHB,DHB,AK,WK,DWO,WL,T) $
QREC=QF*T $
QRAT=(FQA*QA)/(FQR*QREC) $
IF(ABSF(1.-QRAT)) LTE (.001),GO TO 70 $ HAVE WE CONVERGED
IF(QRAT) LT (1.0),GO TO 60 $ ARE WE INSIDE
IF(DELT) LTE (1.0),GO TO 70 $ ARE WE WITHIN 1 FT
A=A+DELT $
GO TO 50 $
70 AMIN=A $
80 PRINT 1600,A,QA,QREC,DIM1 $
A=HB $ DETERMINE ALTITUDE OF TOP
DELT=100000. $
90 DELT=DELT/10. $
100 A=A+DELT $
IF(A) GTE (100000.),A=100000. $ CHECK MODEL LIMIT
DIM2=FL*DFB/(A-HB) $
IF(DIM2) GT (FL),DIM2=FL $
QA=10.**((0.18*EXP(-2.14*LOG10(1.08*DIM2))-0.05) $
CALL TRANS(A,HB,HR,PHB,DHB,AK,WK,DWO,WL,T) $
QREC=QF*T $
QRAT=(FQA*QA)/(FQR*QREC) $
IF(A) E (100000.),GO TO 110 $ CHECK MODEL LIMIT
IF(ABSF(1.-QRAT)) LTE (.001),GO TO 110 $ HAVE WE CONVERGED
IF(QRAT) LT (1.0),GO TO 100 $ ARE WE INSIDE
IF(DELT) LTE (1.0),GO TO 110 $ ARE WE WITHIN 1 FT
A=A-DELT $
GO TO 90 $
110 AMAX=A $
PRINT 1700,AMAX,QA,QREC,DIM2 $
AMAXI=1000.*INTF(AMAX/1000.) $
AMINI=1000.*INTF((AMIN+999.)/1000.) $
IF(AMAXI-AMINI) GT (40000.),DELA=5000.'GO TO 120 $ SET UP A
IF(AMAXI-AMINI) GT (20000.),DELA=2000.'GO TO 120 $ DELTA ALT
IF(AMAXI-AMINI) GT (10000.),DELA=1000.'GO TO 120 $ FROM MIN TO
IF(AMAXI-AMINI) GT ( 4000.),DELA= 500.'GO TO 120 $ MAX ALT
IF(AMAXI-AMINI) GT ( 2000.),DELA= 200.'GO TO 120 $
DELA=100. $
120 AMINI=INTF(AMINI/DELA)*DELA $ BOTTOM ALTITUDE TO NEAREST KFT
LAST=(AMAXI-AMINI)/DELA+1.0 $ NUMBER DELTA ALTS TO REACH TOP
PRINT 1800,DELA $
DO 160 IALT=1,LAST $
A=AMINI+(IALT-1)*DELA $
DELHR=DELA*10. $
HR=0.0 $
130 DELHR=DELHR/10. $
140 HR=HR+DELHR $
SR=SQRTF((A-HB)**2+HR**2) $
DIM3=FL*DFB/SR $
IF(DIM3) GT (FL),DIM3=FL $
QA=10.**((0.18*EXP(-2.14*LOG10(1.08*DIM3))-0.05) $
CALL TRANS(A,HB,HR,PHB,DHB,AK,WK,DWO,WL,T) $
QREC=QF*T $
QRAT=(FQA*QA)/(FQR*QREC) $

```

```

IF(ABSF(1.-QRAT)) LTE (.001),GO TO 150 $      HAVE WE CONVERGED
IF(QRAT) LT (1.0),GO TO 140 $                  ARE WE INSIDE
IF(DELHR) LTE (1.0),GO TO 150 $                  ARE WE WITHIN 1 FT

```

```

150  HR=HR-DELHR $
      GO TO 130 $
      HRMILE=HR/6040. $
      YAXIS(IALT)=A/1000. $      ORDINATE IN KFT
      XAXIS(IALT)=HRMILE $      ABSISSA IN NAUT MILE
      PRINT 1900,A,HRMILE,HR,QA,QREC,DIM3 $

```

```

160  CONTINUE $
      NOPTS=LAST $
      DO 170 I=1,NOPTS $      DATA MUST NOT EXCEED THESE LIM
      IF(YAXIS(I)) LT (.1),YAXIS(I)=.1 $
      IF(XAXIS(I)) LT (1.),XAXIS(I)=1. $
      IF(YAXIS(I)) GT (100.),YAXIS(I)=100. $
      IF(XAXIS(I)) GT (1000.),XAXIS(I)=1000. $

```

```

170  CONTINUE $
      CALL AMPLTPL(XAXIS,YAXIS,NOPTS,1,0) $      PLOT ONE CURVE
      GO TO CARD $

```

```

EXIT  CALL AMNDJOB $      WRAP UP PLOTTING AND TYPE DS
      STOP $

```

```

TXMAX  F/1000. $
TXMIN  F/1. $
TYMAX  F/100. $
TYMIN  F/.1 $

```

```

TFINISH W/END DATA$

```

```

TDAY  W/ DAY $

```

```

TNIGHT W/ NIGHT $

```

```

TFB  F/.001$

```

```

T  F/.1$

```

```

T  F/.002$

```

```

T  F/.135$

```

```

T  F/.0045$

```

```

T  F/.19$

```

```

T  F/.01$

```

```

T  F/.265$

```

```

T  F/.02$

```

```

T  F/.345$

```

```

T  F/.05$

```

```

T  F/.4675$

```

```

T  F/.15$

```

```

T  F/.65$

```

```

T  F/1.0$

```

```

T  F/1.0$

```

```

T  F/2.0$

```

```

T  F/1.09$

```

```

T  F/4.0$

```

```

T  F/1.165$

```

```

T  F/8.0$

```

```

T  F/1.2$

```

```

END $

```

```

ABS      2,EYE SAFE,GO

```

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TEXAS DIVISION

8531 N. NEW BRAUNFELS AVENUE
SAN ANTONIO, TEXAS 78217

Tel: 512 TA4-7373

TWX: 512-571-0939

18 April 1966

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

Subject: Quarterly Progress Report
Contract AF 41(609)-2900

Enclosed are three copies of the Quarterly Progress Report for the subject Contract. This report covers the period from 1 January 1966 to 31 March 1966.

Robert A. Schmall
Associate Principal
Research Engineer

RAS/df

cc: RCH BAC-30
RCH BPS
AMSKR-1

Enclosures

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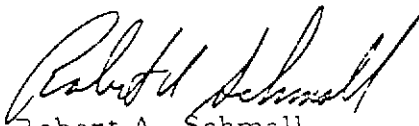
SAN ANTONIO, TEXAS

Progress Report No. 2
Period 1 January 1966 to 31 March 1966

Contract: AF 41(609)-2900

NUCLEAR FLASH EYE EFFECTS TECHNICAL REPORT

PREPARED BY:



Robert A. Schmall
Associate Principal
Research Engineer

APPROVED BY:



George R. Boone
Director
Texas Division

I. INTRODUCTION

This Quarterly Progress Report is submitted to describe activities in connection with Contract Number AF 41(609)-2900 which calls for the preparation of a Technical Report concerning the effects of nuclear flashes on vision.

II. WORK ACCOMPLISHED

Retinal Burn Separation Distances

A. Burn Criteria

At the present time two methods are available for predicting the occurrence of retinal burns. One method relies on the use of threshold irradiance values determined from laboratory experiments using rabbits, and the other method involves various analytic procedures for computing temperature profiles in the retina and adjacent structures. However, attempts to correlate temperature rise with experimentally produced burns have not yet produced satisfactory temperature criteria. Therefore, this technique has been eliminated, at least temporarily, as a method for predicting the occurrence of retinal burns for use in the subject Technical Report.

Of the several sources of experimental retinal burn data, it was decided to use the rabbit burn data obtained on AF Contract

Number AF 41(609)-2906. These particular data are being used because the range of variables is relatively large and all data have been collected in one continuous effort rather than in several separate experiments. Further, the experimental team that obtained these data is readily available for consultation.

B. Source

The selection of a source term for use in determining retinal burn distances must provide for a wide range of weapon yields and detonation altitudes. The yields of interest range from the relatively small tactical weapons to the large strategic devices--and the altitudes of interest range from sea level to above the earth's atmosphere.

For this wide range of interests, there is no single best source model. Most source models have been designed for rather limited interests and are quite adequate for the purposes for which designed. However, when these models are extrapolated to other regions and for other purposes, they often become unsatisfactory. Therefore, it has been decided to use the source as outlined in the "Effects of Nuclear Weapons-1962". While this source may not produce the best prediction for a

particular region, this method is generally accepted as being one of the better general source terms for use within the atmosphere.

For detonations outside the atmosphere, the model developed by the Stanford Research Institute for the Office of Civil Defense seems to offer the best possibility--at present. The region between relatively low altitude detonations and the extra atmospheric detonations will be resolved by interpolation.

These models determine the size and radiation characteristics of the radiating source as functions of time for weapons with yields in the region of interest. The exposure time to be used for evaluation of the hazard to the eyes of air crews will be twice the time to second thermal maximum or a blink reflex time of 150 milliseconds, whichever is shorter. The 150 millisecond blink time may be lengthened slightly if it is found that the rates of change of source characteristics with respect to time are significantly large at 150 milliseconds. This change is not anticipated, but will be introduced if necessary to insure that the overall conservatism of the procedure is not compromised.

C. Atmospheric Transmission

The source characteristics, as selected for this effort, are not sufficiently well defined to justify use of the detailed spectral transmission properties of the atmosphere. Instead, an average extinction coefficient or attenuation factor will be used in determining the atmospheric transmission. Optical density will be determined using a curved earth atmospheric model. This curved earth atmospheric model is presently on file at the School of Aerospace Medicine. However, a flat earth approximation will be used as a matter of convenience for those conditions where there is no significant deviation from the curved earth model.

D. General Procedure

With the above criteria, the basic procedure selected for predicting retinal burns was that outlined in "Prediction of Eye Safe Separation Distances" by E. O. Richey--prepared for presentation at the AGARD Symposium on "Loss of Vision from High Intensity Light". NATO Building, Paris, France, 16-17 March 1966.

This procedure is outlined below:

The radiant exposure to the retina, Q_r , is given by the expression

$$Q_r = f_s(W, H_b, t) \cdot T_e \cdot T_a \cdot T_x / (f \cdot D_{fb})^2,$$

where

$f_s(W, H_b, t)$ is a source term dependent on the yield, height of burst, and exposure time.

T_e is the average transmission of the clear media of the eye.

T_a is the transmission of the atmosphere

T_x is the transmission of optional equipment such as visors, sunglasses, etc.

f is the ratio of focal length to pupil diameter

D_{fb} is the diameter of the fireball.

Exposures calculated using this equation can then be compared to the appropriate threshold data obtained in the laboratory to determine the distance at which the production of retinal damage could be expected.

Initially, distances will be computed assuming T_x is equal to 1.0 (that is no attenuation due to canopy, visors, etc.). This assumption reduces by one the number of variables to be considered in the Report and introduces a degree of conservatism.

III. WORK ANTICIPATED

During the next reporting period, it is anticipated that the retinal burn positioning data will be generated.

It is expected that a review of the flashblindness literature will be completed and the evaluation and selection of a model to be used in the generation of the flashblindness section of the Report will be initiated.

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TEXAS DIVISION


8531 N. NEW BRAUNFELS AVENUE
SAN ANTONIO, TEXAS 78217
Tel.: 512 TA4-7373
TWX: 512-571-0939

4 January 1966

USAF School of Aerospace Medicine
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George R. Boone
Director
Texas Division

GRB/df

cc: RCH BAC-30
RCH BPS
AMSKR-1

Enclosures

TECHNOLOGY INCORPORATED

TEXAS DIVISION

SAN ANTONIO, TEXAS

Progress Report No. 1
Period 1 October 1965 to 31 December 1965

Report No. 2900-65-12
Contract: AF 41(609)-2900

NUCLEAR FLASH EYE EFFECTS TECHNICAL REPORT

APPROVED BY:

A handwritten signature in cursive script, reading "George R. Boone".

George R. Boone
Director
Texas Division

1. INTRODUCTION

This Quarterly Progress Report is submitted to describe activities in connection with Contract Number AF 41(609)-2900 which calls for the preparation of a Technical Report concerning the effects of nuclear flashes on vision.

2. WORK ACCOMPLISHED

The principal activities of the past quarter were concerned with examining current capabilities of the "Temperature Model" (solutions of the heat conductivity equation in terms of retinal temperature distributions) and the "Approximation Model" (retinal irradiance and exposure calculations) relative to the retinal burn prediction problem. At this time it appears that the most appropriate approach is still the use of estimated thermal exposures interpreted for humans in terms of minimal burns produced in the laboratory using pigmented rabbits, i.e. the "Approximation Model" or appropriate variations thereof.

The problem of flashblindness has not yet been considered in detail, but from a cursory review it appears that the best approach presently possible will utilize estimated luminous exposure interpreted in

terms of time of recovery of visual acuity as obtained in laboratory experiments using humans.

For the development of this report, the following outline is being considered:

I. INTRODUCTION

II. GENERAL DISCUSSION

1. Weapon Characteristics
2. Atmospheric Transmission
3. Interaction of Energy with the Eye

III. SIGNIFICANCE OF EXPOSURES

1. Chorioretinal Burns
2. Flashblindness

IV. PREDICTION METHODS

1. Chorioretinal Burns
2. Flashblindness

V. MISSION PLANNING

1. Estimated Safe Separation Distances for Specific Situations
 - a. Skin Burns
 - b. Aircraft Structural Damage

c. Chorioretinal Burns

2. Flashblindness Effects

3. Possible Countermeasures

4. Sample Problems

VI. APPENDICES

VII. REFERENCES

It is suggested that design criteria and areas for additional work be documented separately in as much as this information is intended for a different group of readers.

3. WORK ANTICIPATED

It is assumed that this report should aim at the presentation of simplified prediction techniques, techniques which can be carried out with charts, graphs, and a slide rule or desk calculator. To this end, approximations will be necessary and the differences between these approximations and the more exact formulation must be understood. Thus, comparisons will be made among the various calculational methods in order to establish areas of applicability and limitations.

The results of the experimental program currently in progress at SAM will be incorporated into this report as appropriate and available. Also, efforts to relate calculated temperature histories with experimental observations will be continued with the objective of improving prediction techniques.

APPENDIX A

This Appendix is composed of reviews of three reports dealing with the retinal burn prediction problem.

Vos proposes a theory that retinal burns are caused by the generation of steam in the retinal layers. This assumption has been pretty well disproved by the work done by Spells. Spells has shown that the maximum temperatures existing in the eye are of the order of no more than 25 to 30 degrees centigrade temperature rise. These temperature calculations differ from Vos' by the assumption that the radiant energy is absorbed in some finite thickness rather than at the surface as was assumed by Vos.

SOME REFLECTIONS ON THE DANGER OF AND THE PROTECTION
AGAINST NUCLEAR FLASH BLINDNESS AND RETINAL BURNS - VOS,
FREDERIKSE, WALRAVEN, AND BOOGAARD 1964

In general there are many assumptions in this paper that require additional justification. Some of the assumptions are known to be in error and, on the basis of these, the conclusions presented are not valid.

Some of the erroneous assumptions are, no doubt, due to the fact that Vos et al. do not have access to all pertinent data. However, this does not reduce the consequences of accepting the conclusions presented in the report.

In selecting the minimum distance, the limiting phenomena, as used by Vos, is the overpressure. The limiting overpressure used is about 0.7 psi at sea level. This overpressure level is not limiting on current aircraft, and as a result the minimum distance as used by Vos is too large. By using an allowable overpressure of 2 psi, the minimum distance is 1/2 the minimum distance used by Vos. An allowable overpressure of 2 psi is not too high for some present day fighter aircraft. In fact, for some aircraft, the overpressure limit is higher.

Also for aircraft at some altitude other than sea level, the overpressure is reduced for a given shock strength because the pre-shock pressure decreases as altitude increases.

Vos presents data only for blink times up to 0.1 seconds. Therefore, one cannot evaluate the hazard associated with longer blink time or a delayed blink.

Since 0.1 sec is about the fastest response that can be expected, there is no provision in this report that permits the evaluation of the eye burn hazard associated with longer blink times.

Personally, this writer would not use Vos' conclusions concerning retinal burn if his eyes were involved in an experiment. In general, it is believed that his conclusions are based on insufficient data or misapplication of data.

The data he presents on flashblindness recovery times is complete and (according to Vos) agrees with previous work done in this area.

THE PRODUCTION OF RADIATION BURNS ON THE RETINA AT THE
THRESHOLD LEVEL OF DAMAGE: A LITERATURE SURVEY AND
TENTATIVE MATHEMATICAL THEORY - SPELLS 1964

The basis of all investigations presented in the report are:

- 1) Temperature is the mechanism that causes the permanent damage known as retinal burn.
- 2) Only the temperature at the center of the image is considered in the analysis presented in the paper.

The first assumption appears reasonable at least as a first approximation even though it ignores phototropic effects in a phototropic device.

The second assumption is the one that could stand a closer look. From Carslaw and Jaeger (p.264). The temperature in a semi-infinite solid

heated on the surface, $z=0$, at a constant rate of "F" over an area of radius "a" is:

$$v(r, \theta, z) = \frac{aF}{2K} \int_0^{\infty} J_0(\lambda r) J_1(\lambda a) \left[\exp(-\lambda z) \operatorname{erfc}\left(\frac{z}{2\sqrt{kt}} - \lambda\sqrt{kt}\right) - \exp(\lambda z) \operatorname{erfc}\left(\frac{z}{2\sqrt{kt}} + \lambda\sqrt{kt}\right) \right] \frac{d\lambda}{\lambda} \quad (1)$$

t = time

K = conductivity

k = diffusivity = $\frac{K}{\rho c}$

ρ = density

c = specific heat

Spells then solved equation 1 and obtained:

$$v(0, \theta, z) = \frac{F}{K} \sqrt{\frac{kt}{\pi}} \left[1 - \exp\left(-\frac{a^2}{4kt}\right) \right] + \frac{Fa}{2K} \operatorname{erfc} \frac{a}{2\sqrt{kt}} \quad (2)$$

Then using dimensional analysis he obtained the following relationship:

$$\frac{\sqrt{kt}}{a} = f\left(\frac{Kv}{aF}\right) \quad (3)$$

It should be noted that in performing the dimensional analysis only the variables contained in equation 2 were considered. Therefore, equation 3

should be the expected result from this exercise.

Since K , k , and v are assumed to not vary between experiments, equation 3 can be rewritten as

$$\sqrt{\frac{t}{a}} = f\left(\frac{1}{aF}\right) \quad (4)$$

Spells, in Figure 2 of the report, plots the burn data in the form of equation 4, i.e.

$$\sqrt{\frac{t}{a}} \quad \text{vs} \quad \frac{1}{aF}$$

where:

t represents the exposure time to produce a burn

a represents the image radius

F represents the irradiance

Looking at Figure 2 (Spells), this analysis seems to be lacking as to correlation of the data, and it seems that there exists an additional functional relationship on " a ".

Spells then goes through an analysis where the incident energy is absorbed in accordance with "Beer's Law" ($F/F_0 = \exp(-Cz)$) rather than all the energy being absorbed at the surface.

For this assumption, the following analytic result is obtained.

$$v(o, e, t) = \frac{F}{K} \sqrt{\frac{kt}{\pi}} + \frac{F}{2 \sigma K} \left[\exp(\sigma^2 kt) \operatorname{erfc}(\sigma \sqrt{kt}) - 1 \right] - \frac{F \sigma}{2K} \int_0^{kt} \exp\left(-\frac{a^2}{4x}\right) \exp(\sigma^2 x) \operatorname{erfc}(\sqrt{x}) dx \quad (5)$$

And again, by dimensional analysis, the following relationship to be:

$$\frac{Kv}{aF} = f\left(\sqrt{\frac{kt}{a}}, \sigma a\right) \quad (6)$$

and in particular Spells assumed the form of this relationship to be:

$$\frac{\sqrt{t}}{a} = f\left\{\frac{1}{aF} + \frac{1}{2 \sigma a K v} \left[1 - \exp(\sigma^2 kt) \operatorname{erfc}(\sigma \sqrt{kt})\right]\right\} \quad (7)$$

Equation 7 was obtained by assuming K, v, and k constant as before, and the contribution of the integral of equation 5 to be governed by the independent variable of equation 7 (or equal to zero).

Figure 3 (Spells) shows a plot of the data using the variables of equation 7 for

$$K=k=11 \times 10^{-4}$$

$$\sigma = 60/\text{cm}$$

$$v = 18.6^\circ \text{C}$$

The goodness of fit as shown can be misleading because both terms of

equation 7 contain t and from Table 1 (Spells)

$$\frac{1}{aF} / \frac{1}{2.4a} \left[1 - \exp(4t) \operatorname{erfc} 2\sqrt{t} \right]$$

ranges between approximately 1/4 to 1/20. (Ham's data tends toward the smaller ratio and Jacobson's data toward the larger ratio.)

Also presented in the report is a regression analysis performed on the data by Caldwell. The following equation was fitted:

$$\frac{1}{aF} = A \frac{\sqrt{t}}{a} + B \frac{t}{a^2} + C \frac{\sqrt{t^3}}{a^3} - \frac{1}{a\sigma vKa} \left[1 - \operatorname{erfc} \left(\sigma \sqrt{kt} \exp(\sigma^2 kt) \right) \right] \quad (8)$$

The diffusivity k and conductivity K were assumed to equal 0.0011 and the best values were found for A, B, C, σ , and v by least squares.

For the data presented by Ham, et al. and Jacobson, et al. for an arc source containing both visible and infrared radiation, the following results were obtained:

$$A = 0.804$$

$$B = -0.0096$$

$$C = 0.000094$$

$$\sigma = 20 \text{ cm}^{-1}$$

$$v = 25^\circ \text{C}$$

standard deviation 22.6%

$$\left(\frac{F_{\text{calc}} - F_{\text{obs}}}{F_{\text{obs}}} \right)_{\text{max}} = 48.3\%$$
$$\left(\frac{F_{\text{calc}} - F_{\text{obs}}}{F_{\text{obs}}} \right)_{\text{min}} = -35.5\%$$

and for an arc source visible spectrum only (data of Jacobson, et al.).

$$A = 0.712$$

$$B = 0.0711$$

$$C = -0.0070$$

$$G = 30 \text{ cm}^{-1}$$

$$v = 25^{\circ} \text{C}$$

standard deviation 18.5%

$$\left(\frac{F_{\text{calc}} - F_{\text{obs}}}{F_{\text{obs}}} \right)_{\text{max}} = 54\%$$
$$\left(\frac{F_{\text{calc}} - F_{\text{obs}}}{F_{\text{obs}}} \right)_{\text{min}} = -31\%$$

Spells seems to think that the above are good fits considering that data for one image size has about as much spread as the above curve fit. And "Moreover the results fitted by this equation are those of two investigations hitherto regarded as being somewhat inconsistent with each other".

It should be noted that the above curve fit did not include the long time data.

For short time burns (less than 10 msec) Spels ends up with the following relationship:

$$Ft = \frac{2 P_{cv}}{J} \quad (9)$$

Such short time exposures could be obtained using a laser as an energy source.

COMMENTS

One characteristic of a retinal burn that seems to be overlooked in this analysis is that a retinal burn is associated with a finite area. That is, the burn must be seen by an observer in order that a burn can be reported. The cones and rods have diameters on the order of microns (1 to 3.5 microns), therefore, it seems unreasonable to assume that one "cooked" retina cell can be observed.

Therefore, if instead of looking at the temperature at the center of the image, the temperature of interest is the temperature corresponding to some burn radius r_b . Looking at equation (1) above and letting z equal zero and solving for the temperature at the burn radius:

$$v(r_b, \theta, t) = \frac{aF}{2K} \int_0^{\infty} J_0(\lambda r_b) J_1(\lambda a) \left[\operatorname{erfc}(-\lambda \sqrt{kt}) - \operatorname{erfc}(\lambda \sqrt{kt}) \right] \frac{c \lambda}{\lambda}$$

$$= \frac{aF}{2K} \int_0^{\infty} J_0(\lambda r_b) J_1(\lambda a) \operatorname{erf}(\lambda \sqrt{kt}) \frac{d\lambda}{\lambda} \quad (10)$$

Thus far, attempts to perform the integration indicated in equation (10) have been unsuccessful and hence, the burn temperature was not obtained in a closed form. However, by dimensional analysis, using the variables of equation (10), the following relationship is obtained:

$$\frac{\sqrt{kt}}{a} = f\left(\frac{Kv_b}{aF}, \frac{a}{r_b}\right) \quad (11)$$

Equation (11) differs from equation (3) by the inclusion of the dimensionless variable $\left(\frac{a}{r_b}\right)$.

Carrying the dimensional analysis further to include the fact that the incident energy is not absorbed at the surface, but is attenuated in the z direction by the attenuation law; $\exp(-\sigma z)$, the functional relationship becomes:

$$\frac{\sqrt{kt}}{a} = f\left[\frac{Kv_b}{aF}, \frac{a}{r_b}, \sigma a\right] \quad (12)$$

One form of solution of equation (12) that has been used in convective heat transfer that may work in this problem is:

$$\frac{\sqrt{kt}}{a} = A \left(\frac{Kv_b}{aF}\right)^B \left(\frac{a}{r_b}\right)^C (\sigma a)^D \quad (13)$$

The quantities that are not recorded in the existing burn experiments are:

k - diffusivity

K - conductivity

v_b - burn temperature

r_b - burn radius

σ - extinction coefficient

In order to attempt to correlate the experimental data, it is suggested that equation (13) be fitted for both the data of Ham et al. and Jacobson et al., using accepted values of $k=K=.0011$ (with the appropriate units) and solving for r_b , v_b , and σ as well as the constants A , B , C and D .

If both fits show a correlation in all quantities except r_b , this would explain the apparent inconsistency of results between the two experiments.

TECHNOLOGY
INCORPORATED



TEXAS DIVISION

8531 N. NEW BRAUNFELS AVENUE
SAN ANTONIO, TEXAS 78217
Tel.: 512 TA4-7373
TWX: 512 571-0839

24 June 1965

Headquarters
Aerospace Medical Division
Air Force Systems Command
Post Office Box 35448
Brooks Air Force Base, Texas 78235

Attention: AMSKR-1/A. B. Hawkins, CMSgt., USAF

Subject: Request for Proposal 41-609-65-283


We are pleased to submit the enclosed documents consisting of four (4) copies of our Technical Proposal covering the subject request, plus our Cost Proposal and accompanying certificates and statements.

In the event of contract award to Technology Incorporated, it is requested that provisions be made for progress payments at 75% of total cost incurred.

The Dayton Facility and San Antonio Facility of Technology Incorporated both presently hold Facility Clearances of Secret granted by Central Contract Management Region, Wright-Patterson Air Force Base, Ohio.

It is anticipated that the following named personnel would require access to Secret Restricted Data in the event of contract award. All listed personnel have been cleared for access to Secret by Central Contract Management Region, AF 2300, Wright-Patterson Air Force Base, Ohio:

<u>Name</u>	<u>Position</u>	<u>Date of Clearance</u>
Arthur Francis Muller	Senior Research Mathematician	31 July 1961
Robert Anthony Schmall	Associate Principal Research Engineer	November 1962
Thomas Anthony Alexander	Research Physicist	24 August 1964
Roger Lowell Bassey	Research Physicist	26 January 1964
Cyril Eugene Oelker	Director, Applied Physics Division	25 January 1963
James Edward Gallico	Technical Editor	8 November 1962
Dudley Carver Ward, Jr.	Senior Research Engineer	27 July 1961
Arturo Virgilio Serrano	Research Physicist	20 May 1963
Patrick Woodrow Wilson, Jr.	Junior Research Physicist	6 October 1962
Earl Ross Lawler, Jr.	Junior Research Physicist	15 January 1963
Russell Lee Jeffries, Jr.	Research Engineer	16 January 1961
Brian Evan Arment	Scientific Programmer	8 November 1962
George Ralph Boone	Director, Texas Division	2 November 1962
Vicki Kathleen Girosso	Secretary	13 November 1963
Darlene (NMNI) Fox	Clerk-Typist	21 December 1964


George R. Boone
Director
Texas Division

GRB:vic

Enclosures

COST AND PRICE ANALYSIS - RESEARCH AND DEVELOPMENT CONTRACTS

(This form is to be used in lieu of DD Form 633, as provided under ASPR 16-206. It will be executed and submitted with proposals in response to "Requests for Proposals," for the procurement of research and development services. If your cost accounting system does not permit analysis of costs as required, contact the purchasing office for further instructions.)

FORM APPROVED
BUDGET BUREAU NO. 22 - R208

PURCHASE REQUEST NUMBER
RFP 41-609-65-283

Technology Incorporated
3090 Richfield Center, Dayton, Ohio 45430

TITLE OF PROJECT
Preparation of a Nuclear Flash Eye Effects Technical Report

DETAIL DESCRIPTION

1. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	TOTAL ESTIMATED COST (Dollars)
Senior Research Physicist	700		
Research Physicist	800		
Mathematician - Programmer	300		
Jr. Research Physicist	1200		
Technical Editor	400		
Technical Support	800		
TOTAL DIRECT LABOR			
2. BURDEN (Overhead - specify) DEPARTMENT OR COST CENTER	BURDEN RATE	X BASE	BURDEN (\$)
Overhead	70%		
TOTAL BURDEN			
3. DIRECT MATERIAL		EST COST (\$)	
Miscellaneous Items		100.00	
TOTAL MATERIAL			\$ 100.00
4. SPECIAL TESTING (Including field work at Government Installations)			
TOTAL SPECIAL TESTING			
5. SPECIAL EQUIPMENT (If direct charge - specify in Exhibit B, reverse)			
TRAVEL (If direct charge)			
a. TRANSPORTATION		1,500.00	
b. PER DIEM OR SUBSISTENCE		300.00	
TOTAL TRAVEL			\$ 1,800.00
CONSULTANTS (Identify - purpose - rate)			
Neurological Support in Selected Areas		400.00	
TOTAL CONSULTANTS			\$ 400.00
6. CONTRACTS (Specify in Exhibit A on reverse)			
7. OTHER DIRECT COSTS (Specify in Exhibit B on reverse - explain royalty costs, if any)			
TOTAL DIRECT COST AND BURDEN			
8. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of item nos.)			
TOTAL ESTIMATED COST			
9. FEE OR PROFIT (State basis for amount in proposal) ASPR 3-808			
TOTAL ESTIMATED COST AND FIXED FEE OR PROFIT			

FORM 633-4
SEP 60

LT Col Dan Brown
HQ AFM&A/SGPT
202-767-5078
70A-655-Box
Flashlight
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RESEARCH and

TECHNOLOGY

DEVELOPMENT

A
TECHNICAL PROPOSAL

FOR

PREPARATION OF A NUCLEAR FLASH

EYE EFFECTS TECHNICAL REPORT

PROPOSAL NUMBER 65-504-A

Headquarters
Aerospace Medical Division
Brooks Air Force Base, Texas

Request for Proposal Number

41-609-65-283

TEXAS DIVISION

3531 N. NEW BRAUNFELS AVE. • SAN ANTONIO, TEXAS

Lt Col Dan Brown
HQ AFM&A/SGPT
202-767-5078
70A-655-Box
Flakelindren
Sutland People etc

24 June 1965

Technology Incorporated
San Antonio, Texas

TECHNICAL PROPOSAL
RFP 41-609-65-283

PREPARED FOR:

Headquarters
Aerospace Medical Division
Brooks Air Force Base, Texas

APPROVED BY

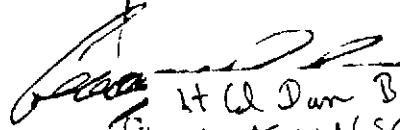

G. Lt Col Dan Brown
D. HQ AFM&A/SGPT
T. 202-767-5078
70A-655-Box
Flanklin
Sutland Records etc

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1. INTRODUCTION AND SUMMARY

Technology Incorporated is proposing the preparation of a technical report on nuclear flash eye effects with emphasis on aircrew operations for use by military planners. The objective of the proposed technical report will be to assist operations personnel and aircrews in planning and carrying out missions with the least possible eye hazards.

The proposed research team is currently working in the area of nuclear flash eye effects and includes personnel with experience in physics, mathematical analysis, computer programming, nuclear weapons effects, handbook preparation and other closely related areas.

Technology Incorporated has gained considerable experience in the field of ocular effects. This experience, including participation in nuclear tests, theoretical analysis of thermal effects and performing ocular studies in the laboratory, provides Technology Incorporated personnel with unique abilities in this specialized field. As a result of a history of participation in work concerning nuclear flash eye effects, literature covering the greater part of the state of the art has been accumulated. In order to thoroughly

utilize this type of information, a Company library is maintained by a full-time librarian.

Other advantages of Technology Incorporated are its location, size, and operational liaison. The offices and laboratories of the Texas Division are within the city of San Antonio, Texas. This location permits close coordination between interested Ophthalmology Department personnel and Technology Incorporated's project team.

The facilities of Technology Incorporated and the personnel who would be assigned to this task, are cleared to handle classified information up to and including Secret Restricted Data.

2. STATEMENT OF THE PROBLEM

Several research efforts, testing programs, and studies have been performed which cover almost all aspects of ocular effects from nuclear detonations. This includes nuclear detonation characteristics, atmospheric transport, eye protective measures and devices, and physio-pathological eye effects. To date there has been no comprehensive compilation of this available nuclear flash eye effects and countermeasure information into a homogeneous state-of-the-art publication. The School of Aerospace Medicine is planning to consolidate this information into a Technical Report from which military strategists may plan missions which are within the framework of reliable eye safe separation distances, and which contains the criteria by which to choose the best eye protection. The need for having this information readily available under a single cover is evidenced by the number of requests from military commanders for safety recommendations for a specific situation, especially where aircrew operations are involved. Such a report would not necessarily be concerned with the exacting conditions used in positioning for test purposes, but the more general problem of successful completion of a military mission.

Thermal radiation from a nuclear weapon can affect the eye in various ways. These are grouped into two main categories: (1) flashblindness, which is a relatively temporary effect, and (2) the chorioretinal burn, which is a more permanent injury. If the observer is looking directly at the fireball, the energy will be focused onto a small spot on the retina and a retinal burn may result at much greater distances than those which produce skin burns. If the observer is not looking directly at the fireball, the likelihood of a burn is much less, but he may have a temporary loss of vision due to the bleaching effect from the increased light level. Information on countermeasures is needed to protect military aircrewmembers from these possibilities. Safe separation distance information is also needed as a guide as to when it would be judicious to use a protective device.

In order to achieve the clarity and utility needed in such a Technical Report, and to cover the factors which are essential in considering every aspect of any given situation, the suggestions listed in the statement of work will be utilized, along with other sections and data which are discussed later in this proposal.

Only materials and data approved by the procuring agency will be used in the preparation of this Technical Report.

3. APPROACH TO THE PROBLEM

3.1 General

In order to be effective, a Nuclear Flash Eye Effects Technical Report must be written so that the user of the report can readily understand and apply the contents to his particular situation. Therefore, the prime consideration in the preparation of the Report will be the presentation of the data, and construction of the format so as to provide the necessary information in a manner that can be readily applied by military commanders.

Technology Incorporated proposes to collect, analyze, differentiate and synthesize all available and approved information on nuclear flash eye effect which endanger the successful completion of military missions. The literature will be distilled for its value to military commanders and mission planners and presented in a useful and concise Technical Report form. The included data will be in graphical or tabular form with complicated mathematical expressions omitted. Safe separation distances based on the pertinent parameters will be contained in nomographs or tables and

only arithmetical procedures will be used for computation facilitating quick decisions and minimum error. The originating agency and appropriate libraries will be visited. Authorities in the field of ocular effects in both private and government institutions, will be consulted. Previous questionnaires will be re-evaluated and local commanders, through the Contracting Agency, will be asked to outline their problems and recommend areas of immediate importance to their mission.

No attempt will be made to generate new data. This report will be based only on past research. For example, a simplified method for retinal burn safe-separation-distance which has been used quite successfully for quick, rough estimates in the past is present in Operation Dominic Project 4.1 POR.

3.2 Specific

This compendium might be composed of the following sections:

1. Preface
2. Introduction
3. Ocular Response to Nuclear Weapon Detonation

4. Nuclear Weapon Detonation Characteristics
5. Countermeasures
6. Criteria for Mission Planning
7. Example Problems
8. Bibliography
 - a. Non-technical
 - b. Technical
9. Appendix
 - a. Definitions of Terms
 - b. Device Design Criteria
 - c. Future Areas of Investigation

1. Preface

This section will serve as an over view of the report given in outline form permitting quick retrieval of pertinent information elsewhere in the report. It will also contain a short discussion of the report's purpose.

2. Introduction

This section will discuss the problem, its history, and summarize the sections contained in the report with attendant usefulness of each section.

3. Ocular Response to a Nuclear Weapon Detonation

This section will cover the aspects of flashblindness and chorioretinal burns induced by thermal radiation. It will define the effects, characterizing the type of impairment and its relation to crewmen function, and present representative data on flashblindness recovery time and retinal burn thresholds. The discussion will be limited to the effect of thermal radiation incident on the cornea including ambient lighting conditions.

4. Nuclear Weapon Detonation Characteristics

This section will present discussion and representative data of nuclear weapon detonation characteristics. It will be concerned primarily with the thermal radiation produced and its delivery to the cornea of the eye. Weapon type, yield, height of burst, atmospheric conditions, cloud formations and geometry of source to receiver will be the main parameters discussed.

5. Countermeasures

This section will contain a complete discussion of accepted countermeasures and their value for given situations.

Included will be protective procedures, on the ground and in an aircraft, and mechanical devices with limitations and advantages listed and compared.

6. Criteria for Mission Planning

This section will contain all data needed for mission planning as pertains to ocular effects and will not contain information on mission planning in general or that of delivery. Data will be presented in graphical or tabular form and an estimate of errors given. Data will include information on flashblindness recovery time as a function of incident thermal energy, rate of delivery, size of fundus impairment and burn thresholds. Data will be given on thermal energy from the source as a function of weapon type and yield, slant range and atmospheric attenuation and scattering. Skin burn, and aircraft safe separation distances will be correlated with ocular safe separation distances.

7. Example Problems

Information contained in the last section will be used in example problems to familiarize the reader with the

parameters and techniques involved. An outline chart method will be used whose form can be followed for all contingent cases and will contain all pertinent steps of computation with an estimate of range value and probable error given for each step. This will ensure that planning will be uniform and complete and confidence can be engendered in the planner.

8. Bibliography

The bibliography will be divided into two parts; (a) non-technical literature and (b) technical literature. Part "a" will consist of military planning reports written primarily for commanders and military planners containing information directly useful to the mission. Part "b" will be of wider scope containing information a student in the field would use. This part will also contain all material not in Part "a" which is used in preparing this report.

9. Appendix

This final section will be in three parts; (a) Definition of Terms, (b) Device Design Criteria, and (c) Future Areas of Investigation. Part "a" will define all terms used in

this report facilitating understanding of the material and minimizing ambiguities. Part "b" will give parameters needed, including "worst case", in design of a working eye protective device. Pilot reactions to previous designs will also be included. Part "c" will outline inconsistencies in present data including insufficient investigation and recommend areas for future research and analysis.

3.3 Summary

In the construction of this Technical Report the intended purpose of the report must always dictate the contents and presentation of the contents. The technical content must be restricted to that which is required for the mission planners and technical nomenclature avoided whenever possible. The content should also be as clear and concise as possible so as not to unduly burden the reader. Extreme care must be taken to insure that only currently approved (by the procuring agency) material be used in this technical report. A partial bibliography on the following pages indicates the copious supply of printed information available.

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4. RELATED EXPERIENCE

Technology Incorporated has conducted research in numerous related areas which would enhance the overall objective of the proposed effort. The research summary to follow outlines these areas and indicates the meaningful contribution Technology Incorporated has made toward advancing the state-of-the-art in this area of nuclear weapons effects.

- Supplementing the research initiated under Contract AF 41(609)-8334 and continued under Contract AF 33(657)-11557, Contract AF 41(609)-2437, also sponsored by the Aerospace Medical Division, involves refinement of a mathematical model of retinal burns from nuclear flashes. Another task requires preparation of nuclear fireball source tables which show for various yields and altitudes the spectral irradiance and dimensions versus time. Related to this requirement is the writing for the Philco S-2000 a program to handle spectral data as direct input to a mathematical model for flashblindness. Also retinal burn data from laboratory tests are being analyzed in the light of similar data from weapons tests.
- Contract AF 41(609)-2464 for the USAF School of Aerospace

Medicine involves research on the ocular effects of thermal radiation. Included is the design, fabrication, and calibration of a high-intensity thermal source for experimental use. Program objectives include the experimental definition of criteria for thermal radiation causation of flashblindness and chorioretinal burns, developing and testing techniques to predict flashblindness and chorioretinal burns suffered under various exposure conditions, and developing and evaluating devices as well as techniques to protect against visual impairment from thermal radiation exposure. Particular aims seek development of a mathematical model capable of predicting flashblindness severity and duration, wavelength, and post-exposure illumination level; expansion of flashblindness threshold data; and methods to identify minimal burns and to relate them to pertinent parameters, such as image size, irradiance, and retinal location.

- Under Contract AF 33(657)-10686, Technology Incorporated is analyzing existing nuclear effects prediction formulae to verify the safe-escape calculations used in ADC and TAC Nuclear Weapon Delivery Handbooks. In the area of structural vulnerability, and of particular interest, Technology Incorporated has just

completed the preparation of two documents summarizing the state-of-the-art aircraft vulnerability. These documents, RTD-TDR-64-1, "Vulnerability of Aeronautical Systems to Nuclear Effects. Volume I, Methods of Structural Analysis," and Volume II, "Applications of Structural Analysis," required an exhaustive literature survey and a compilation of available lethal structural volumes. In addition, it was necessary from a user's point of view to include a unique method of presenting lethal volume data. This was done by "slicing" the volumes into altitude increments and presenting these increments in plan view. Such a procedure will allow more reasonable assessment of Soviet and U. S. aircraft vulnerability. Also included in Volume II was a section covering crew vulnerability to flashblindness/retinal burn effects in general. Present emphasis is being placed upon formulation of a computer program which will treat structural dynamic response to nuclear blast loads.

- Working in support of the Air Force Special Weapons Center under Contract AF 29(601)-6788, Technology Incorporated is performing various statistical tests on nuclear test data to develop a statistical design procedure for shock isolation systems. Tasks include dividing air-blast induced ground shock records into sets

of different wavelength patterns, statistically analyzing the records in each set for population grouping, estimating the significant parameters defining each set distribution function, deriving from these functions the response distribution function of a mechanical system, finding the probability of the mechanical system failure due to each input set, and finally giving a detailed statistical design procedure for shock isolation systems.

- Nuclear blast effects upon in-flight aircraft were investigated in the research effort under Contract AF 33(657)-8373. Nuclear phenomena were examined to determine the heat, overpressure, gust velocity and radiation magnitudes affecting a specific weapons system. These levels were utilized to ascertain the tolerance levels of each parameter and the structural limits for particular types of aircraft.
- Under Contract N 140(131)-75271 B(X), Technology Incorporated aids the Naval Material Laboratory in installing, calibrating, and operating the instrumentation to record the thermal and visible radiation effects of nuclear detonations. Such data, recorded on magnetic tape, oscillogram, camera film, and strip chart, are being processed.

- Initiated under Contract N 140(131)-75231 B(X), research on the thermal and visible radiation effects of nuclear detonations continues under Contract N 140(62462)-76804B for the Navy's Applied Science Laboratory. The processing of Operation Dominic data is a major phase of this effort. In the development of a testing capability, instrumentation systems to record data on oscillograms and magnetic tape are being designed, fabricated, and tested. These systems will incorporate specially designed transducer packages. Various light sources are being employed in the development of calibration systems for laboratory and field use.

5. REPORTS

Technology Incorporated will submit informal progress reports, in triplicate, at the end of three, six, and nine months and a preliminary draft of the final report at the end of ten months. The informal progress reports will include existing portions of the final report, difficulties encountered during the reporting period and the remedial action taken, and a statement of anticipated activity during the subsequent reporting period. The final technical report will be submitted at or before the end of twelve months. Both the preliminary and final technical report will adhere to the following directives:

5.1 Instructions for Preparation:

The report will be prepared in accordance with the provisions of USAF School of Aerospace Medicine Publication, "A Guide for Preparing Material for Publication," April 1963, (or respective supplementing or superseding documents).

5.2 Preliminary Draft:

5.2.1. Technology Incorporated will submit a typed, double-spaced preliminary draft manuscript of the Technical Documentary Report to the USAF School of Aerospace

Medicine for technical and format review. The preliminary draft shall be complete, including (as applicable) all test results, conclusions, tables, illustrations, and appendices.

- 5.2.2. Technology Incorporated will be responsible for insuring that the report is editorially correct and that it conforms to accepted common usage and good practices in scientific and technical writing for a generally broad audience.
- 5.2.3. When the preliminary draft is returned, Technology Incorporated will make the changes, additions or corrections designated by the USAF School of Aerospace Medicine. The corrected copy will be called the approved draft.
- 5.2.4. Technology Incorporated will make every effort to insure that the preliminary draft manuscript is complete and accurate, thus eliminating the need for submitting a second preliminary draft. However, if the USAF School of Aerospace Medicine determines

that the first preliminary draft requires extensive rewriting or additions requiring further technical review by the USAF School of Aerospace Medicine, the first preliminary draft will be returned for appropriate revision. The Contractor will return the revised draft for approval of the USAF School of Aerospace Medicine.

5.2.5. Final Drafts: Reproduction Copies for Photo-offset Printing: After receipt of the approved draft, Technology Incorporated will prepare an original typed bound copy in accordance with the requirements of Paragraph A and submit this copy to the USAF School of Aerospace Medicine for final format review, approval, printing, and distribution. In addition, Technology Incorporated will prepare and forward 50 Xerox quality bound copies of the final draft.

6. CHRONOLOGY

Technology Incorporated is prepared to begin work on this effort immediately upon the awarding of a signed contract. The work called for in this proposal will be completed within a period of twelve months.

7. PERSONNEL AND MANAGEMENT

The work proposed by Technology Incorporated will be conducted under the general supervision of Mr. George R. Boone, Director, Texas Division.

It is anticipated that a senior physicist will be available for this project as principal investigator. He would be assisted by Messrs. J. E. Gallico, A. F. Muller, R. A. Schmall and T. A. Alexander. All team members have had considerable previous experience in the proposed work. Should the need arise, ophthalmological consultants will be made available through the Company.

In addition, other scientific members of the staff will be available to contribute their special skills to the solution of the various problems associated with this research effort. Their resumes are presented on the following pages.



PERSONNEL





ARTHUR F. MULLER, Senior Research Mathematician

Education: A. B. Mathematics, St. Benedicts College
M. S. Mathematics-Statistics, Kansas State University
Completed additional course work in Mathematics at
the University of Wichita and the University of Dayton

Professional
Affiliations: Society for Industrial and Applied Mathematics
American Statistical Association

Publications: Minimum Distances for Retinal Burn, AMRL-TDR-63-56
Co-author - A Study Covering Utilization of Statistical
Data in Relation to Design Criteria Analysis Techniques

Experience: Serving as an applied mathematician, Mr. Muller is now
engaged principally in the mathematical analysis of data
utilizing the Philco 2000 to reveal the thermonuclear
effects on the chorioretinal region of the human eye. He
had previously conducted an extensive study on the utili-
zation of statistical data in relation to design criteria
analysis and to the design of IBM 7090 programs for aero-
nautical loads programs.

During prior employment with the Boeing Company, Wichita,
Kansas, Mr. Muller's main responsibility was the analysis
of engine-to-wing configurations, using mission programs
written specially for them. Mr. Muller also worked on the
analysis of structures, the resolution of aerodynamic prob-
lems, and the design of IBM 709 programs with FORTRAN
and machine language. His various efforts included the
performance of cross-correlations, auto-correlations,
mission program design, regression analysis, and the
writing of several FORTRAN programs.

Before the Boeing Company employment, Mr. Muller taught
mathematics at St. Benedicts College, Atchison, Kansas.



ROBERT A. SCHMALL, P. E. , Associate Principal Research Engineer

Education: M. S. in Aeronautical Engineering, University of Cincinnati
Bachelor of Mechanical Engineering, University of Dayton

Professional Affiliations: American Society of Mechanical Engineers
Dayton Society of Professional Engineers

Publications: "The Transfer of Thermal Radiation from a Point Source to a Plane Receiver, Both Source and Receiver Located Between Two Lambert Planes," ASD Technical Report 61-282, June 1961.

Design and Operation of a Space Rendezvous Simulator, AF APL TR-64-130, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, October 1964. (coauthor)

Experience: As a staff member of the company's Astronautics Division, Mr. Schmall applies the theories of mass and energy transport, dynamics, and kinematics to pertinent research. Included among his activities have been the investigation of the thermal and pressure effects of nuclear detonations on manned and unmanned aeronautical systems; the computer programming of thermal and over-pressure inputs resulting from nuclear detonations in multiple combinations of yield, burst height and atmospheric conditions; the design, development, and test of an advanced wind shear probe; the design of a hydraulically actuated acceleration system; and the design and evaluation of various space maintenance concepts and equipment. Mr. Schmall has a broad programming experience including use of the Donner Analog computer, machine language and ALGOL on the Burroughs 205 and 220, and FORTRAN on the IBM 1620 and 7094.

Before joining Technology Incorporated, Mr. Schmall was a research engineer for the University of Dayton Research Institute where he worked on heat transfer in aircraft structures, the transport of energy through the atmosphere, the determination of aircraft response in the delivery of nuclear weapons, and the measurement of laser outputs. He was also an instructor in the Mechanical Engineering Department of the University

As a Project Engineer for the Duriron Company, Inc., he was responsible for the design, development, and test of heat exchangers, pumps, valves, and filters for the chemical process industry.



THOMAS A. ALEXANDER, Research Physicist

Education: B. S. in Physics, Louisiana State University
M. S. in Mathematics, Trinity University

Publications: "Experimental Calibration of Semiconductor Detector Pulse-Height Response to Protons," Technical Documentary Report, No. SAM-TDR-63-21, 1963. (coauthor)

Experience: To simulate light from nuclear weapons so that nuclear radiation effects may be more thoroughly investigated for an Air Force Flashblindness program, Mr. Alexander has been engaged in research to generate such light from various high-energy sources. Using data from Project Dominic in the Philco 2000 electronic computer, he derived eye image flux densities. Also he compared measured values with theoretical ones based on weapon yield.

While associated with the U. S. Air Force, Mr. Alexander made nuclear measurements of charged particles at the Berkely and Minnesota accelerator facilities. Related tasks involved his evaluating solid state radiation detectors. To this end, he acquired several silicon detectors from various manufacturers and tested them for dead layer, junction width, noise figure, gammas, charged particles, and neutrons. In addition, to modify and calibrate the whole body counter, he equalized the response of photomultiplier tubes by separating crystal calibrations on a large shielded plastic well counter and summed the outputs of all tubes in two sets of six for conjunctive coincidence counting and display of Compton edges on a multichannel analyzer. Furthermore, a design of a transistorized circuitry for a missile shot required his developing a circuit to sample solid state radiation detectors with various shielding materials, providing calibration levels, and feeding signals to a single telemetry channel.



ROGER L. BESSEY, Research Physicist

Education: B.S. in Physics, Yale University
M.S. in Physics, Purdue University

Professional
Affiliations: Sigma Pi Sigma

Experience: Mr. Bessey has been applying various statistical and computational techniques to nuclear detonation data to determine the threshold positions and distances for permanent visual damage and temporary flash blindness. Various types of atmospheres, which govern the degree of nuclear effects transmission, the relative altitudes of the nuclear burst and the participating personnel, and the types of protective eye devices are among the vital parameters of his research.

On the faculty of Purdue University, he served in the Physics Department. While engaged as a research physicist for the Army Quartermaster Corps, he conducted flashblindness experiments with laser models; by using 1 Mev Van der Graaf generator and resistivity measurements, he studied energy for production of vacancies and interstitials in thin metal foils; and he constructed a shock tube.



C. E. OELKER, Ph. D., Director of Applied Physics Division

Education: B. S. in Electrical Engineering, University of Cincinnati
M. S. in Physics, University of Cincinnati
Ph. D. in Physics, University of Cincinnati

Professional Affiliations: Tau Beta Pi, Eta Kappa Nu, Sigma Xi, American Physical Society, Society for Industrial and Applied Mathematics, The Institute of Management Sciences, Instrument Society of America.

Publications: "Design of a Two-Dimensional Ballistocardiograph," Journal of Clinical Investigation, Vol. XXIX, No. 9, pp. 1219-1226, September 1950.

"A Ballisto-Vectorscope," Journal of Clinical Investigation, 1953.

"Discussion of Iridium-Rhodium Thermocouples for Gas Temperature Measurements up to 3500°F," proceedings of the ASME Combustion Conference, 1955.

Experience: As director of Technology Incorporated's Applied Physics Division, Dr. Oelker is responsible for the technical direction of all division projects. Current projects in his division include research in photogrammetry, reconnaissance, information retrieval, and systems analysis.

As president, manager, and co-founder of Randam Electronics Inc., Dr. Oelker was responsible for the company efforts in engineering, production, accounting, and sales. The company develops, designs, and manufactures test equipment, instrumentation, intercommunication sets, and automatic controls.

In the employ of the Cincinnati Division, Bendix Corporation, Dr. Oelker was the director of the Engineering Department. In this role he supervised the development, design, and manufacture of new products, including nuclear instruments, nuclear reactor instrumentation, time-of-flight mass spectrometers viscometers, and automatic missile checkout equipment.



C. E. OELKER, Ph. D. , Director of Applied Physics Division (Continued)

As the manager of the Applied Mathematics Department, Crosley Division, Avco Manufacturing Corp., he organized, staffed, and directed five groups: digital computation, analog computation, analysis, planning, and computer development. Types of services embraced by these groups included system analysis, special-purpose computer design, and digital and analog computer systems. While serving as the manager of the Missile System Development for this company, he was responsible for the group effort in developing system concepts for a bomber defense missile, a surface-to-air missile, a surface-to-surface missile, an anti-radiation air-to-surface missile, and missile components including fusing systems.

When assigned to the technical direction of the Instrument Development Unit, General Electric Company, Dr. Oelker guided company development of instrumentation to test jet engines and jet components, including compressors, combustion chambers, afterburners, controls, and turbines. Related efforts involved the development of automatic data processing equipment, computers, recorders, transducers, traversing equipment, and new instrumentation techniques.



JAMES E. GALLICO, Technical Editor

Education: B.S. (cum laude), Fordham University
Graduate Courses in Electronics, Georgetown University
Graduate School
U. S. Navy Certificate in Long-Range, Celestial, Aerial
Navigation

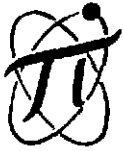
**Professional
Affiliations:** Society of Technical Writers and Publishers
Ad Dexterum Guild

Experience: At Technology Incorporated, Mr. Gallico is responsible for the completion of all final reports, brochures, and instructional and operational manuals. His experience in scientific and engineering communication and teaching covers more than 25 years.

In the employ of the University of Dayton for 16 years, he served in the following roles: professor of mathematics, editor of all prospective student literature (more than a million pieces were individually distributed), and technical editor for the University's Research Institute; he edited and prepared for printing more than 200 technical publications. A brochure prepared for the Non-metallic Materials Laboratory, Air Force Materials Central, served as a guide for a U. S. Army study to establish a similar laboratory.

With Foster Wheeler Corporation, which consists of five engineering divisions, he edited for two years its monthly technical journal "Heat Engineering"; this publication distributed in bulk to all leading engineering schools is used as reference literature.

Before serving during World War II as a commissioned officer in the U. S. Navy, where he graduated from three Naval schools to instruct pilots in long-range, celestial, aerial navigation, he taught mathematics and physics at Loyola College of Baltimore.



DUDLEY C. WARD, JR., Senior Research Engineer

Education: B.A.E., Alabama Polytechnic Institute

Professional
Affiliations: Institute of Aeronautical Sciences
Pi Tau Sigma National Honorary Mechanical
Engineering Fraternity

Publications: (1) Structural Design Criteria Reliability Integration
(2) An Investigation of Variable Wall Diffusers
(3) A Study Covering Utilization of Statistical Data in
Relation to Design Criteria Analysis Techniques
(4) Structural Flight Loads Data from F-101A and
F-101C Aircraft - ASD-TDR-62-912 (Vol. II)
(5) Maneuver Flight Loads Data from RF-101C Air-
craft - ASD-TDR-62-923

Experience: Mr. Ward is a member of the Aeronautical Staff of
Technology Incorporated. In this capacity, he has been
responsible, under Air Force Contract AF 33(616)-8467,
for the research associated with utilizing statistical data
in relation to design criteria analysis techniques. Under
Contract AF 33(657)-8373, Mr. Ward was responsible,
in conjunction with ASD, for the safe positioning of test
aircraft during Operation DOMINIC and safe escape
calculation for the delivery and ground zero aircraft.
He is presently supervising the review of the F-106,
F-101B, and F4H-1 Nuclear Weapons Delivery Hand-
books for possible revision and modification. This
review includes rigorous structural analysis based
upon expected thermal and overpressure inputs.

While with the U. S. Air Force, Mr. Ward supervised
the determination of failure modes and the determination
of those techniques which were utilized to re-establish



DUDLEY C. WARD, JR. (continued)

aircraft air worthiness. Mr. Ward was formerly associated with McDonnell Aircraft Corporation where he was responsible for the determination of aerodynamic loading of the Talos 6cl wing. This included combining aerodynamic influence coefficients (in matrix form) to obtain an aeroelastic loading distribution, determining the critical wing loading condition as influenced by free skin temperature, and using this critical condition to qualify the wing in static test.

Mr. Ward was associated with the GAM-72 Missile Program where he worked on such problems as shear and bending moments, theoretical nose pressures, and structural design criteria for low level launch configurations.

Under Air Force Contract AF 33(616)-6677, he was responsible for the recommendations concerning Missile Structural Design Criteria Requirements and as a result of the research necessary to define these requirements, was responsible for developing the application of power spectral density techniques to gust loads analysis.

Prior to joining McDonnell Aircraft Corporation, he was associated with Eastern Airlines, Inc. where he worked on loads problems and flight operations.

Mr. Ward is presently attending the Ohio State Graduate School where he is studying for an advanced degree in Aeronautical and Astronautical Engineering.



ARTURO V. SERRANO, Research Physicist

Education:

B. S. in Physics, St. Mary's University
Armament and Electronics Systems Maintenance
Officer Course
Electronic Countermeasures Systems Maintenance
Officer Course
GAM77 Systems Maintenance Officer Course

Experience:

Mr. Serrano has been analyzing various effects on electronic systems, subsystems, and their components in steady state, space, and transient environments. The effects include EMP, thermal radiation, and other phenomena emanating from nuclear detonations; also alpha, beta, gamma, neutron, and cosmic radiations existing in nonnuclear-weapon environments. From these studies, he predicts the overall effect that a particular environment will have on the performance of the systems. Then after defining circuit hardening requirements and techniques, he recommends design changes. Also, he establishes the design criteria for instrumentation systems to be subjected to nuclear radiation environments in tests to determine weapon system vulnerability to nuclear weapons effects.

As a maintenance officer in the U. S. Air Force, Mr. Serrano was active in armament and electronics (avionics) maintenance for B-52 aircraft and AGM28 (formerly GAM77) missiles. Also he performed analyses of material failure trends to determine mean time-to-failure rates of electronics systems, such as compasses, gyro compasses, radio compass, astro compasses, UHF and VHF transmitters and receivers, bomb-nav radar systems, electronic warfare systems, radar controlled tail turrets, mechanical, digital and analog computers, inertial guidance, and flight control systems, arming and fuzing systems, and all subsystems and equipment related to aircraft-missile interfaces. In addition, he correlated component failure data with malfunctions experienced within systems to determine those components which have a significant effect on the reliability and effectiveness of the overall weapons systems.



PATRICK W. WILSON, JR., *Junior Research Physicist*

Education: B. S. in Physics, St. Mary's University
 Studies in Electronics in U. S. Navy

Experience: Assigned to basic research on the human eye, Mr. Wilson has been active in the design, fabrication, calibration, and operation of instrumentation systems to facilitate this research.

While serving the U. S. Navy, Mr. Wilson maintained and operated various electronic mechanisms, including airborne communication, navigation, countermeasures, and antisubmarine warfare equipment.



EARL R LAWLER, JR , Junior Research Physicist

Education: B.S in Physics, St. Mary's University
Graduate courses in physics, St Mary's University

Experience: Mr. Lawler has been active in the design, fabrication, and operation of a high-intensity source which simulates the light emanating from a nuclear detonation. Such a source will be used in investigations to determine the effects of high-intensity light on the animal and human eye. His efforts also involve the design, fabrication, calibration, and operation of instrumentation systems.

With Simmes Electronics, he was engaged in the design of transistorized switching circuits, such as Schmitt trigger and multivibrator circuits. His efforts there also involved artificial intelligence and pattern recognition.

While serving with the Air National Guard, he attended the Electronics School and Weapons Control Systems Mechanics School, both at Lowry Air Force Base, Colorado. Courses covered the MG-10 and MG-13 radar systems incorporated in the F-101 and F-102 fighter-interceptor aircraft.

When employed in the Plant Engineering Department of the Southwestern Bell Telephone Co., he was concerned with problems related to the location, distribution, and loading of cables.



RAUL SAN MARTIN, M. D., Associate Principal Biomedical Scientist

Education: M. D. University of Mexico Medical School
B. S. University of Mexico
M. S. in Biomedical Engineering, Drexel Institute of Technology
Graduate training in Biophysics and Biochemistry, University of Michigan
Graduate training as a Research Fellow in Physiology at Harvard University Medical School
Visiting Fellow in Hematology at the Pratt Diagnostic Hospital, Tufts University Medical School

Professional

Affiliations: The Physiological Society of Philadelphia
The American Association for the Advancement of Science
The New York Academy of Sciences

Publications: "Embriological and Physiological Bases for the Surgical Treatment of Intestinal Obstructions" Doctoral thesis, Mexico, D.F., May, 1949, Facultad de Medicina, Universidad Nacional Autonoma de Mexico.

"Vomiting in Infants, Classification, Physiopathology and Treatment of the Electrolytic Unbalance." Raul San Martin M. D., Francisco Rivadeneyra M. D., and Carlos Garcia de Leon M. D., Pediatric Society of Michoacan. Awarded the Nestle's Annual Prize for Pediatrics. Morelia, Michoacan, Mexico. 1956.

"Phase Plane Analysis of the Ventricular Pressure Curve" Thesis for Master of Science in Biomedical Engineering degree. Philadelphia, Pennsylvania, June, 1964. Drexel Institute of Technology.

Experience: The responsibilities of Dr. San Martin include coordinating research in Biomedical Engineering. He is also responsible for the exploration of new ideas and methods, as well as for their applications in the biomedical and space physiology.



RAUL SAN MARTIN, M. D. (continued)

From 1962-1964, Dr. San Martin was awarded a grant as a Special Fellow from the United States Public Health Service to enable him to pursue his biomedical engineering training at Drexel Institute of Technology. During this time, he studied several courses in mathematics, physics, circuit theory, analog computer, systems engineering, biosystems, instrument theory and others.

While serving as a member of the faculty of the Jefferson Medical College, Philadelphia, Pennsylvania, his work consisted of laboratory guidance to the medical students and advisory work for graduate students. During this time, he was working on a project which consisted of intercommunicating the coronary sinus with the left ventricular chamber in order to improve the coronary circulation.

At the University of Michoacan Medical School, Mexico, for six years, Dr. San Martin was Chairman of the Department of Physiology and full-time professor, lecturing in Human and General Physiology to the first- and second-year medical students. During this time, he was in charge of designing the new laboratory of Physiology for the school, selecting the respective equipment and organizing the laboratory program for both subjects. He was responsible for the introduction of the flame photometer into the clinical practice in Morelia. He developed a model for the demonstration of Einthoven's projections on the standard leads. He developed a method for the gravimetric quantitation of water in the blood.

Before this appointment, Dr. San Martin filled the same post for two years at the University of Puebla Medical School, Puebla, Mexico. During this time he was also Chief of the Clinical Laboratories of the Hospital Latino-Americano of that city. Previously, in this same hospital (200 beds), he had worked as a night doctor for two years before receiving his W. K. Kellogg Physiology Training Fellowship.



RAUL SAN MARTIN, M. D. (continued)

In 1951 he started this fellowship at the University of Michigan where he received special training in Biophysics and Biochemistry. In 1952, at Harvard Medical School, as a research fellow, he participated in a project that led to the publication: "Reduced Sodium Excretion in Dogs with Mild Valvular Lesion of the Heart and in Dogs with Congestive Failure". Am J of Ph. Vol 180: No. 2, Feb. 1955. A. C. Barger, R. S. Ross and H. L. Price. In 1953, Dr. San Martin was a Visiting Fellow in Hematology and Clinopathology under Dr. William Damesheck at the Pratt Diagnostic Clinic of the New England Center Hospital



RUSSELL L. JEFFRIES, JR., Research Engineer

Education: Bachelor of Electrical Engineering
University of Dayton

Professional
Affiliations: Institute of Radio Engineers

Experience: Mr. Jeffries has been designing and developing a ground station to receive, digitize, and transcribe onto magnetic tape atmospheric data telemetered from a free-fall wind shear probe. Concurrently, he has been investigating the requirements for future monitoring and recording of thermal radiation in the visible spectrum from nuclear detonations as well as processing such data acquired from previous tests. His previous activities in electronic research were mostly in the domain of bioengineering. He was engaged in the design, fabrication, and test of a system to measure the mechanical impedance of the human body; in research on the vibration effects on human subjects; in the determination of the tolerances for high- and low-frequency sinusoidal and random vibration; and in the investigation of the effects of low-frequency sinusoidal vibration on visual acuity, speech transmission, and hearing. Other physiologically oriented research included abrupt deceleration tests on components of the Mercury and Gemini spacecraft, research on retinal burns and flash blindness due to nuclear detonations, development of instrumentation to measure nuclear effects, design and development of a physiological monitor to measure vital human functions, and design and development of analog computers applicable to bionics studies.

During previous employment with the University of Dayton Research Institute, Mr. Jeffries was responsible for the maintenance, installation, and modification of various types of data reduction equipment and its associated input-output devices. He also worked on the design and development of a digital-to-analog converter and an automatic test scoring machine used by the University's Guidance Center.



BRIAN ARMENT, Scientific Programmer

Education: B. A. in Mathematics, Wilmington College

Experience: Mr. Arment has been designing a system for the normalization and diagnostic analysis of electrocardiographic data. Engaged principally in the processing of physiological data, Mr. Arment wrote several computer programs to perform the following operations: correlation of respiration and heart rates of human subjects experiencing various events before undergoing impact tests, analysis of data from dogs subjected to vibration tests to determine their respiratory and hemodynamic responses, and computation of parameters associated with human subjects used in impact tests for center-of-mass shift studies. Using nuclear detonation data, he wrote a computer program to normalize and integrate the total irradiance and radiant exposure.

In the performance of his assignments, he has acquired a working knowledge of all phases of data processing, from the reduction of raw data in analog form to the digital conversion and subsequent analysis of the refined data. He has written programs in FORTRAN II and IV for the IBM 7094 computer and has operated the D. E. C. PDP-1 computer.



RICHARD E. HORN, Ph. D., Consultant

Education: Ph. D. in Optometry, Ohio State University

- Publications:
- (1) A Method for Simulated Night Flying During Daylight Hours, WADC Technical Report 54-505, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, October 1954.
 - (2) Infrared Skiascopic Measurements of Refractive Change in Dim Illumination and in Darkness, WADC Technical Note 55-479, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, August 1955.
 - (3) "Infrared Skiascopic Measurements of Refractive Change in Dim Illumination and in Darkness," J. O. S. A., Vol 46, No 1, January 1956.
 - (4) Visual Recovery Times from High Intensity Flashes of Light, WADC Technical Report 58-232, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, October 1958.
 - (5) "Visual Recovery Times from High Intensity Flashes of Light," Amer. J. of Optometry, Vol 36, No 12, December 1959.
 - (6) Flashblindness during Nuclear Operations, WADC Technical Report 58-642, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December 1959.

Experience: Serving as a consultant to Technology Incorporated, Dr. Horn provides support in research on flash blindness and retinal impairment resulting from nuclear weapon detonations and on the development of design criteria for eye protective devices. Included among vital parameters studied are various types of atmosphere, which govern the degree of nuclear effects transmission, the relative altitudes of the nuclear burst and the participating personnel, and the types of protective eye devices.

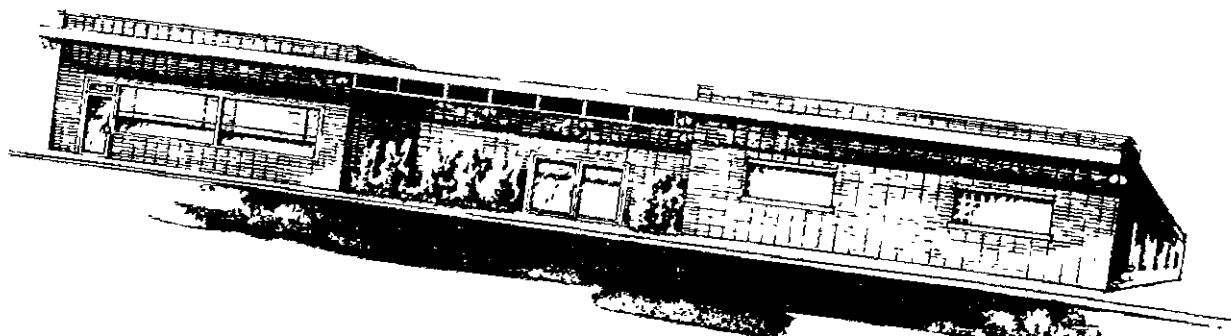


RICHARD E. HORN, Ph.D., (continued)

In addition to the private practice of optometry, Dr. Horn's activity has included research for the Vision Section, Aerospace Medical Research Laboratories. While engaged as a project engineer and later as an assistant chief in this laboratory, Dr. Horn's efforts included the following studies: eye protection from nuclear weapon detonations, space vision, basic parameters of visual function, visual recovery from high-intensity light flashes, eye-protective equipment, electromechanical goggles, phototropic materials, night and space myopia, infrared retinoscope, simulation of night flying during the daytime, and nuclear radiation effects on the eye.



FACILITIES





During the summer of 1965 Technology Incorporated will move into a 30,000-square foot plant to be constructed on a 12-acre site within a half mile of the center of both the Wright-Patterson Air Force Base complex and the new State University. The new plant will encompass and expand the present two Dayton facilities which are described in the following paragraphs.

The present principal Dayton facility is located at 3090 Richfield Center, Dayton, Ohio 45430. This modern complex has a 14,000-square foot floor area and contains administrative, engineering, research, and data processing sections. It is completely air conditioned and soundproofed throughout. Research and engineering areas are separated from supporting areas to insure an efficient and creative environment for scientific personnel. Staff members have ready access to a comprehensive library containing current product catalogs, technical publications, DDC documents, military specifications, technical books, periodicals, and journals. A laboratory and model shop equipped with electronic test apparatus and machinery are integral sections of the main plant; also a "clean" room enables manufacturing and products to meet exacting NASA standards. Drafting, technical writing, printing and photographic reproduction, and other support activities are also available.

The second Dayton facility, a complete machine shop facility at 5132 Bower Avenue, Dayton, Ohio, provides an additional 5800 square feet of fabrication capability.

Another recent acquisition is the plant at 8531 N. New Braunfels Avenue, San Antonio, Texas 78217. This plant, comprising 10,000 square feet, was acquired to provide facilities for the newly organized Texas Division of Technology Incorporated to serve more adequately our customers in the Southwest. It is staffed and equipped for research, design, development, and manufacturing functions.

Engineering liaison offices to serve our customers in the East, Southwest, and West are located, respectively, as follows: 7250 Edsall Road, Alexandria 12, Virginia (Tel.: 703, 354-6311); 5731 Gulf Freeway, Houston 23, Texas (Tel.: 713, WA-3-8775); and 6305 Woodman Avenue, Suite 106, Van Nuys, California (Tel.: 213, 781-2720).

Technology Incorporated holds a Department of Defense Secret facility clearance. The accounting, purchasing, and property control procedures now in effect have been approved for Government contracting.

Spacious, well-lighted work areas now totaling about 35,000 square feet will expand to more than 45,000 square feet by the summer of 1965.



... reception room



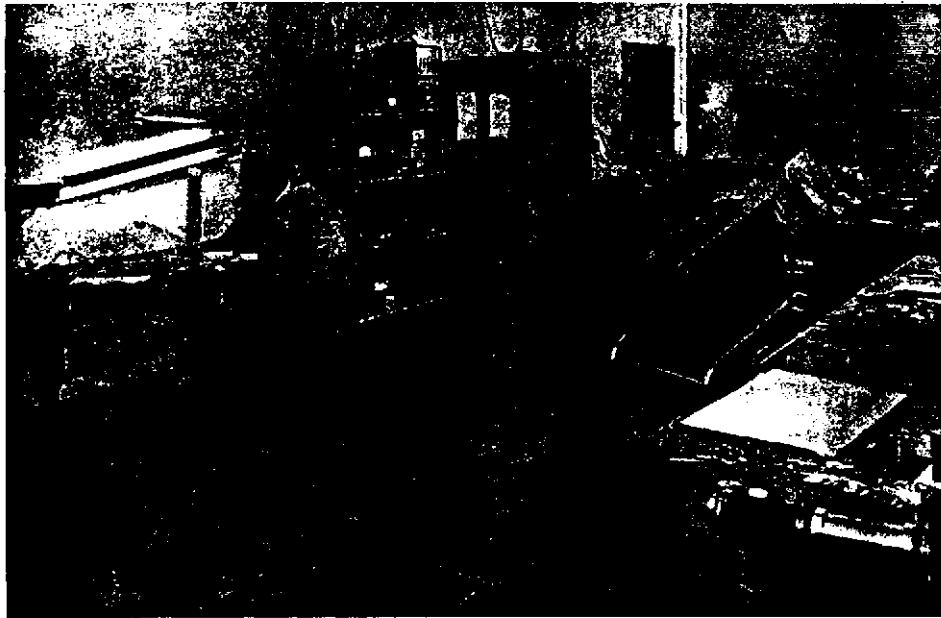
... conference room



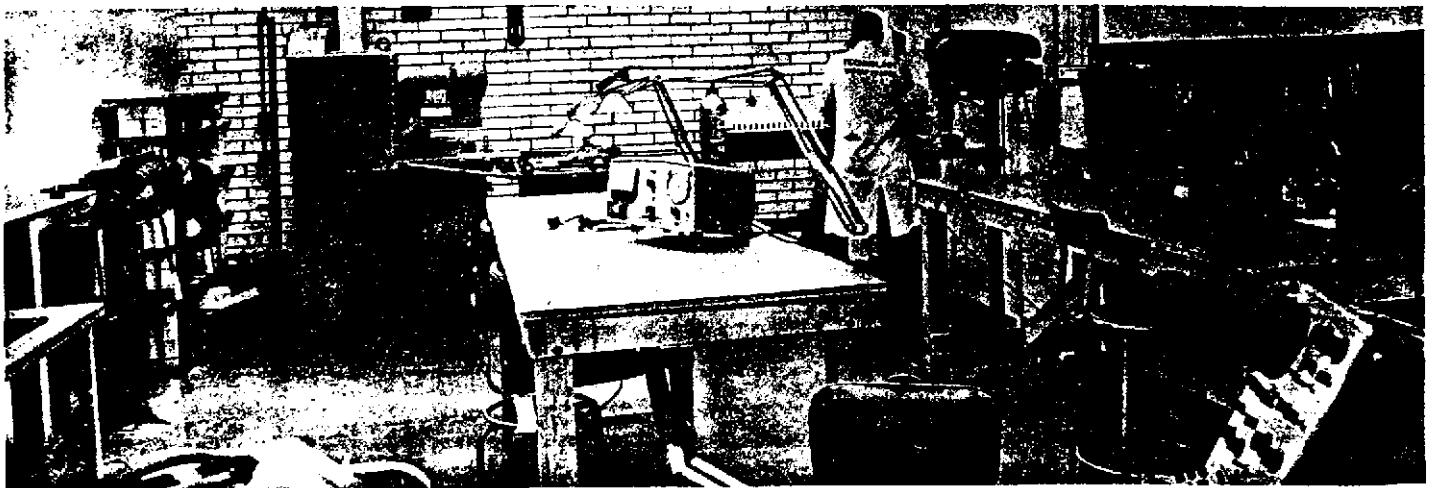
Air-conditioned, soundproofed facilities and separation of research and engineering rooms from supporting areas ensure optimum working conditions

LABORATORIES

Implementing the Quality Control program, the Clean Room ensures that manufacturing and products comply with the cleanliness requirement of any Government agency.



Developmental and environmental test laboratory. Among the prototypes tested here are flow meters and modular electronic packages for applications such as airborne blood-pressure measuring systems. Exhaustive cold chamber and oven tests ensure functional stability over a wide range of temperatures.



Precision work and minor fabrication are performed in this facility supporting the electronics laboratories.

SUPPORT FACILITIES

Library contains current product catalogs, technical publications, DDC documents, military specifications, periodicals, and journals.



Engineering Design and Technical Art Department. Here are prepared all engineering drawings, schematics, flow charts, and technical illustrations presented in reports, specification sheets, and manuals.

Xerox Model 914 copier and Ditto Model L-16 offset duplicator for single and multiple copy reproduction.



Nu-Arc plate burner and Xerox Nu camera for offset reproducible equipment for cutting, collating, binding.



LABORATORY TEST EQUIPMENT

<u>Quantity</u>	<u>Description</u>
1	Air Sampler, Sentry Model 25101
1	Amplifier (hi-fi), Model EE02254
1	Amplifier (high gain), Tektronix Type D
1	Amplifier (strain gage), Central Eng. Model #3AC
1	Balance (triple beam), Ohaus Scale Corp. - max C. 2600g
1	Barometer, Aloe Model #V9120
1	Barometer, Precision Instrument Model 9434
1	Bridge (general radio), Orthonull CRL
1	Bridge (impedance), Heath, 1B-2A, #009-07794
1	Camera, Graflex Model #CF905
1	Capacitester, Model CT-1
2	Clean Bench, Farr Model C-6
1	Counter, Hewlett-Packard Model #522B
1	Counter (frequency), Hewlett-Packard, #521C1909
1	Counter (frequency), Hewlett-Packard, #032-04585
1	Curve Tracer (transistor), Technology Incorporated
1	Curve Tracer (transistor), Tektronics, Type 575
20	Decade (capacitance)
4	Decade (capacitance), Heath
2	Decade (capacitance), Model CDA-5
2	Decade (capacitance), Model CDB-5
4	Decade (resistance), Heath
5	Decade (resistance), Eico Model 1171-W
8	Decade (resistance), Leeds and Northrup
21	Decade Resistors
1	Distortion Analyzer, Hewlett-Packard, HO 2330B
1	Drill Press (precision), Dumore Model 16-021
1	EPUT and Timer, Beckman Model 735OR
1	Fan (centrifugal), Clarage Model 309-G Type O
1	Flow Element (precision, laminar), Meriam Model 50MH10-1
1	Flow Element (precision, laminar), Meriam Model 50MJ10
1	Flowrator, Fischer and Porter Model 10A2735A-LK
1	Generator (R. F. signal)
1	Generator (R. F. signal), SG-8
1	Generator (signal), Washington Inst. Tech. Model #43-41
1	Generator (signal), Ferris Model #18FS
1	Generator (sine square), AG10
1	Grinder, Dumore Model 1-111
1	Heat Exchanger, Prefex Model RBS-640-132
1	Indicator (temperature)
1	Laminar Flow Element, Merriam Inst. Model 50MH10-1
2	Magnifying Lamps, Luxo
1	Magnifying Light (5 power), 8 in. diameter
2	Manometer (inclined tube), Merriam Model 40HE35WM
10	Manometer (water)
1	Manometer (mercury), multiscale
1	Meter (distortion), HD-1
1	Meter (grid dip), Millen Model F718
1	Meter (grid dip), Millen, w/coils
2	Meter (microamp), Simpson (Shell)
1	Meter (multipurpose), International Model M2548-2
1	Meter (meg. ohm), General Type 1862-C
1	Meter (volt), Ballantine Lab. Model #302B
1	Meter (volt), D. C., Fluke, Model 801
1	Meter (volt), Hewlett-Packard Model #400H



DATA PROCESSING AND REPRODUCTION FACILITIES

<u>Quantity</u>	<u>Description</u>
7	Calculator (desk), Marchant
1	Camera, Crown Graphic "45"
1	Diazo Machine, Brunning 42", "Revolute"
1	Nu-Arc Plate Burner
1	Offset Duplicator "Ditto", Model L-16
15	Oscillograph Reader, Benson-Lehner Model Oscar "K"
1	Photographic Stereo Viewer with Key Punch and Type Readouts
1	Photograph Reader, Benson-Lehner Model Oscar N-2 with Key Punch and Type Readouts
1	Planimeter, A. Ott
15	Punch (key), IBM Model 026
1	Punch (reproducing), IBM Model 519
1	Scale (variable), Gerber
1	Sorter, IBM Model 082
1	Tabulator (accounting), IBM Model 407
1	Verifier, IBM Model 056
2	Xerox No. 4 Camera
1	Xerox 914 Copier

MODEL SHOP FACILITIES

<u>Quantity</u>	<u>Description</u>
1	Anvil (Swedish steel), 30 in.
1	Blocks (precision gage), Weber
1	Calipers (vernier), Lufkin - 6 in.
1	Calipers (adj. feel), Lufkin - 1 to 20 in. inclusive
1	Compressor (air), Milwaukee Model C202 - 2 in. by 3 in. stroke, 1 1/2 H. P.
1	Drill (flexible shaft), Craftsman - 1/2 H. P.
1	Drill (hand), Black and Decker - 1/2 in. capacity
1	Drill (hand), Shopmate - 1/2 in. capacity
1	Embossing Tool, Dymo
1	Engraving Tool, Speedway
1	Etcher and Demagnetizer (electrical), Daytrol Model 100
1	Filing Machine (table), Oliver
1	Gage, Height, Brown and Sharpe - 18 in.
1	Gage, Height, Starret Model 454 - 12 in.
1	Gage, Small Hole (1/2 ball), Lufkin Model 785 - 1/8 in. to 1/2 in.
1	Gage, Telescoping (rod type), Lufkin Model 79L - 1/2 in. to 6 in.
1	Gage, Wire (round), General Model 20 - No. 1 to No. 36
1	Gage, Lay-out (round-base, standard), Fairfield - 6 in.
1	Gage, Radius (flat, Brown and Sharpe) - 1/32 in. to 1/2 in.
2	Gages, Surface (flat base), Lufkin - 6 in. and 12 in.
1	Grinder (surface), Covell Model 7A - 11 3/4 in. Height, 6 in. x 12 in. chuck
1	Grinder (internal-external), Brown and Sharpe Model 3275 - #1, 18 in. between centers
2	Grinder (6 in. snag), Tool Line Model 2645551 - polishing and buffing wheels
1	Grinder (10 in. snag), Standard Model 622445 - polishing and buffing wheels
1	Grinder (hand), Dumore Model 8-021, #21900 - 0 to 1/8 in. Jacobs Chuck



EXPERIENCE





Ascertaining accurate levels of human tolerance to forces of abrupt deceleration through test and calibration was the prime objective of Contract AF 33(616)-6970. This effort, conducted for the Aerospace Medical Research Laboratories, involved the design of instrumentation and a "fail-safe" control system for the test equipment, the Vertical Deceleration Tower located at Wright-Patterson Air Force Base. A built-in analog computer for data optimizing before recording was designed, constructed, and incorporated into the recording system.

Under Contract N 62269-2264, sponsored by the U. S. Naval Air Development Center, Technology Incorporated is expanding the capability of a multivisual optical device designed for nuclear flash blindness experimentation. Phenomena related to flash blindness are being studied to evolve additional types of test parameters. Predetermined by digital computation, data for test parameters, such as target-surround luminance, flicker rates, and target positioning, will be fed through tape or cards as simulated input to the optical device and the resulting signal output will be supplied to an analog-to-digital converter to generate a data format compatible with a standard electronic computer.

To acquire flight loads data for Contract AF 33(616)-7593, Technology Incorporated installed and maintained recording systems in thirty F-101A and C and thirty RF-101 aircraft, assigned to air bases in England, France, and Libya. From the recordings selected data were extracted, processed, and analyzed to determine the load spectrum for fatigue life evaluation. Such findings may lead to the verification or revision of structural design criteria.

Under subcontract PO-4364 with IBM, Technology Incorporated has been applying various techniques to incomplete photogrammetric data to study methods for rectifying photographic images. Rectified by determining photogrammetric parameters obtained from ground control data, object plane coordinates are derived as functions of image plane coordinates. Projective geometry concepts are employed; and specific techniques include iterative solutions, least mean square fits, and solutions of over-determined systems of linear over-homogeneous equations. From estimates of image and object plane coordinate covariances used to derive transformational matrices, variances of object plane dimensions are derived. Photogrammetric parameters are solved through matrix manipulations involving inverse, transpose, and multiplicative operations. The IBM "Storm" Matrix Manipulation program is being used to solve over-determined systems of linear equations.

Research completed under Contract AF 33(616)-7440 included the design, fabrication, calibration, and test of a complete electronic instrumentation system involving three RF telemetry links for in-flight testing of B-58, RS-70, and Dyna Soar Emergency escape systems. Anthropomorphic dummies and two B-58 escape capsules were instrumented; a semiautomatic control system for the instrumentation and ejection sequencing was installed in the test vehicle; and a mobile van facility with test data receiving, recording, discrimination, playback, and display capabilities was provided.

Contract AF 33(616)-7887, sponsored by the Bionics and Neurophysiology Section of the Aerospace Medical Research Laboratories, entailed the design and construction of experimental equipment and simulation systems for research on living information handling systems. Included among the developmental equipment was an electronic analog, based on the functioning of biological systems, to simulate neurosensory networks for the conversion of sensory information, such as a light or sound pattern, to a form compatible with neuron network analogs or adaptive computers.

To assist Lloyd Brothers Inc. in gaining the Federal Drug Administration approval of Segontin, a drug for angina patients, Technology Incorporated used statistical techniques to determine the efficacy of the drug. Responses of angina patients, each given the drug and a placebo, make up the data acquired by doctor-conducted tests.

Under Contract AF 33(616)-7927 with the Aerospace Medical Research Laboratories, Technology Incorporated conducted drop tests from the Inclined Test Facility at Wright-Patterson Air Force Base to acquire impact data on various test subjects. The test results were processed and analyzed with the aid of the IBM 7090 computer and associated equipment.

As a subcontractor to AiResearch under the prime contract NAS 9-150 for the National Aeronautics and Space Administration, Technology Incorporated designed and manufactured nine Mass Flowmeters, each to measure linearly oxygen flow from 0.2 to 0.5 lb. per hr. in Apollo spacecraft. The company has developed a line of other compact, self-contained, linear Mass Flowmeters for various scientific applications requiring the measurement of gas flow.



Sponsored by the Ohio State Research Foundation under Contract AF 33(616)-6288, ML-201, Technology Incorporated completed the following tasks: a general synopsis of data processing methods and equipment, a summary of the general operation of a computer and its limitations when performing various functions, and a number of solutions to various data processing problems.

A long-range planning program to establish the structural loads measurement requirements for future aerospace vehicles was developed under Contract AF 33(616)-7406. Study of the vehicles, including an advanced boost-glide vehicle, a recoverable satellite, a manned satellite, and a lunar vehicle for a "soft" moon landing, was pursued from ground handling through landing or impact to determine the conditions of the critical loads. Instrumentation systems for two configurations of the Blue-Scout were designed. After a study of all available and planned instrumentation was completed, instruments needed for load measurements were specified and a transducer handbook was compiled.

To determine the performance characteristics of clustered parachutes under infinite mass conditions, Technology Incorporated conducted under Contract AF 33(657)-7985 a series of wind tunnel tests. Objectives were determination and presentation in report form of the effects of the type of parachute canopy, of the number of parachute canopies in a cluster, of the canopy reefing ratio, and of the riser length on the drag and static stability characteristics of clustered configurations. A sting balance capable of measuring the two component forces of the cluster configurations up to a 25-degree angle of attack was designed, fabricated, and instrumented.

With the sponsorship of the Protective Equipment Section, Aerospace Medical Research Laboratories, and under Contract AF 33(657)-9417, Technology Incorporated developed the structural design of a support system to evaluate the performance of personnel in a simulated environment with continuous acceleration and vibration forces. Other efforts included the integration of a system comprising a five-channel physiological monitor. Also the complete system was evaluated and calibrated during impact tests. An analog computer and the IBM 7090 digital computer were used to process the data.

The Physiological Monitor—a portable, self-contained, completely automatic electronic unit to measure the vital body functions of critical-care patients—has been designed and developed by Technology Incorporated personnel. Extensive tests have proved the accuracy and reliability of the Physiological Monitor in measuring continuously pulse rate, respiration rate, temperature, and both systolic and diastolic blood pressure. Units are commercially available through medical equipment distributors.

Contract AF 33(657)-9537 involves the design, fabrication, and test of a system to measure the mechanical impedance of the human body, the whole body and various portions of it. Other research on this contract includes continued research on the vibration effects on human subjects, determination of the tolerances for high- and low-frequency sinusoidal and random vibration, and investigation of the effects of low-frequency sinusoidal vibration on visual acuity, speech transmission, and hearing.

Under Contract AF 33(657)-10686, Technology Incorporated is analyzing existing nuclear effects prediction formulae to verify the safe-escape calculations used in ADC Nuclear Weapon Delivery Handbooks. This analysis will lead to the writing of a nuclear weapons effects IBM 7090 program for the ASD Offensive Systems Office. In addition, voids in existing knowledge of systems capability are being determined to recommend future test efforts to the Air Force.

Determination of the levels of human tolerance to forces of abrupt deceleration through test and calibration was initiated for the Aerospace Medical Research Laboratories under Contract AF 33(616)-6970. The effort, continued under Contract AF 33(657)-10010, includes related research for AMRL in conjunction with NASA, such as the current studies of abrupt deceleration tests conducted on components of the Mercury and Gemini space vehicles.

As purchased by the U.S. Navy under Contract N 62269-2122, Technology Incorporated supplied two units of the Mass Flowmeter, which were designed, fabricated, and tested by company engineers. Measuring linearly the mass flow of gas, the Mass Flowmeter is a compact, self-contained unit constructed for operation in space environments. Each of the units supplied to the Navy is 2 1/4 in. in diameter by 3 in. in length, weighs approximately 12 oz., and has a range of 0 to 0.4 lb. per min. and a linearity of $\pm 2.5\%$ of full scale referred to the best straight line.

Sponsored by the Aeronautical Systems Division under Contract AF 33(657)-9845, Technology Incorporated instrumented seventy C-130 aircraft to record three in-flight parameters: airspeed, altitude, and acceleration. Instrumented aircraft were assigned to six air bases: four in the states of Tennessee, Texas, and Hawaii; one in Okinawa; and one in France. Presentation of the processed and analyzed data in the form of a load spectrum for fatigue life evaluation of this aircraft type completed the program. The findings will be used in the review of design criteria.



Development of digital methods for the automatic and cyclical processing of biological signal information is the general requirement of Technology Incorporated's effort under Contract AF 41(609)-2267, sponsored by the Air Force School of Aerospace Medicine, Brooks Air Force Base. These methods will be used to determine the presence of significant information in biological data, supplied in analog or digital form on various media, such as magnetic tape and strip charts. The effects of variable rates of digitizing on biologic signals will be investigated. Novel as well as classical diagnostic methods will be utilized and their capabilities compared both to establish the most efficacious techniques and to lead to still other novel approaches. Techniques to be developed are intended to establish criteria for normality and specified abnormalities through the application of the methods to known populations.

Through the acquisition, processing, and analysis of Flight Technical Error data under Federal Aviation Agency Contract FA-WA-4542, Technology Incorporated is determining the random deviation of rotary- and fixed-wing civil aircraft from their intended cruising altitudes. This information will be reviewed for the possible revision of current altitude separation distances. Phenomena being studied include the design stability of the aircraft and its systems; effects of airspeed, turbulence, gusts, and altitude; inaccuracies of the automatic flight control systems; and pilot technique.

Engaged in the first phase of a four-year study for the Air Force Personnel Research Laboratory, Brooks Air Force Base, Technology Incorporated under Contract AF 41(609)-2294 processed data written on military questionnaires. The questions were designed to generate criteria, that is, a set of specific responses, which could be used to project early officer-career tenure. Original information was key punched and verified, and computer programs were written for the statistical analyses leading to the evolution of the criteria.

As a subcontractor to Giannini Controls Corporation under P.O. E-24906, Technology Incorporated designed, fabricated, and successfully tested a digital translating system to extract and digitize in-flight data recorded on magnetic tape by the Giannini VGH Statistical Recorder. Data are fed directly to an IBM 7090 computer. Another requirement was the computer analysis of the data to determine the recorder capability; for this purpose, computer programs were written in FORTRAN IV and MAP.

Under Contract AF 41(609)-2328, sponsored by the Air Force Personnel Research Laboratory, Brooks Air Force Base, Technology Incorporated used two methods to determine the extent to which supervisory officers consistently give high or low ratings to officer personnel, regardless of their objective merits, on Officer Effectiveness Reports. Determination of characteristics distinguishing high and low raters from raters in general was a secondary objective. Data supplied on tape were sorted for appropriate information selection and modified for desired format presentation. Regression program routines were selected from the company library and other programs were specially written to analyze the data.

Under Federal Aviation Agency Contract FA-WA-4590, Technology Incorporated is conducting a pilot program to record structural loads on civil transport helicopters. These aircraft have been instrumented to record the structural flight loads parameters affecting their performance in normal operational environments. Such data are being processed and analyzed to determine the optimum parameters, data processing techniques, and data presentation arrangements for future full-scale helicopter structural loads recording programs.

To assist the Air Force School of Aerospace Medicine in determining an acceptable gaseous environment for men during prolonged spacecraft occupancy, Technology Incorporated is conducting research, under Contract AF 41(609)-2334, to evaluate the responses of men and animals subjected to the breathing of pure oxygen at decreased pressure. Specially designed double-wall test cells enabling high-accuracy control of the gaseous environment will be used to investigate the oxygen toxicity effects on the hematology, histology, and enzymology of the test subjects; also the surface activity of material lining the lungs of the subjects will be analyzed.

Collaborating with the Air Force Avionics Laboratory, Technology Incorporated has been directed under Contract AF 33(615)-1000 to apply statistical computer techniques to data for the evaluation of control systems and components involved in navigation and guidance systems. Included among the tasks are the fit of a Weibull distribution to component reliability data to reveal life characteristic information, particularly that generated by gyros; the comparative evaluation of several system reliability models developed for guidance and control systems; the introduction of various parameters into computer subroutines to simulate satellite or ICBM interception in order to determine the feasibility of acquiring reliable solutions to intercept guidance and control problems; and the evaluation of existing techniques of error analysis and synthesis used in studying guidance system performance, including determining the effect of ignoring non-linear terms and the manner in which errors are propagated during the boost and coast portions of a trajectory.



To assist the U. S. Army Transportation Research Command (TRECOT) in deriving new design criteria for three types of Army Aircraft, Technology Incorporated is conducting, under Contract DA 44-177-AMC-221 (T), a flight loads program. Two aircraft of each of the following three types were instrumented: OV-1A "Mohawk," fixed wing; UH-1B "Iroquois," helicopter; and CH-47A "Chinook," helicopter. All instrumentation systems record altitude, airspeed, outside air temperature, and normal acceleration at the center of gravity; the UH-1B and CH-47A systems also record rotor rpm, longitudinal cyclic stick position, and collective stick position; and unique to the UH-1B system is the recording of the rotor torque. Upon completion of the reduction and analysis of the data, Technology Incorporated will present the processed data in a form suitable for the derivation of load spectra.

Under Contract NASw-970 sponsored by the National Aeronautics and Space Administration, Technology Incorporated is studying the feasibility of its proposed method of treating 8-channel flight loads data to derive load spectra for aircraft design and service life estimates. In contrast to the current method of presenting distributions of parameter frequencies obtained by measuring all parameters whenever one of their traces peaks, the proposed method would produce a statistically derived model for each of a set of distinct maneuvers which constitute normal operation. The maneuver models would consist of a mean time-history curve for each basic parameter and the distribution of observed values about the mean. If the proposed method proves feasible, statistical techniques could be more validly applied to the derivation of structural loads. In addition, the maneuver models derived for one aircraft could be used to derive structural loads on other aircraft with similar missions by using estimated values for the latter's inertial response and aerodynamic characteristics.

Contract AF 41(609)-2464 for the USAF School of Aerospace Medicine involves research on the ocular effects of thermal radiation. This research requires the design, fabrication, and calibration of a high-intensity thermal source for experimental use. Program objectives include experimentally defining criteria for thermal radiation causation of flashblindness and chorioretinal burns, developing and testing techniques to predict flashblindness and chorioretinal burns suffered under various exposure conditions, and developing and evaluating devices as well as techniques to protect against visual impairment from thermal radiation exposure. Particular aims seek development of a mathematical model capable of predicting flashblindness severity and duration as a function of parameters, such as flash intensity and duration, wavelength, and post-exposure illumination level; expansion of flashblindness threshold data; and methods to identify minimal burns and to relate them to pertinent parameters, such as image size, irradiance, and retinal location.

Under Contract AF 41(609)-2446 for the USAF School of Aerospace Medicine, Technology Incorporated established at Brooks Air Force Base a capability of extracting analog data from oscillograms and converting it to digital form on punch cards. The company adapted and installed a semiautomatic oscillogram reader together with a key punch so that the equipment could handle biomedical data and generate a digital output compatible with the Philco S-2000 computer. Other services included the construction of reading overlays, the computation of calibration factors, the preparation of operational procedures and various data arrangements, and the instruction of the Air Force personnel assigned to the reading operation.

Supplementing the research initiated under Contract AF 33(657)-8334 and continued under Contract AF 33(657)-11557, Contract AF 41(609)-2437, also sponsored by the Aerospace Medical Division, involves refinement of a mathematical model of retinal burns from nuclear flashes. Another task requires preparation of nuclear fireball source tables which show for various yields and altitudes the spectral irradiance and dimensions versus time. Related to this requirement is the writing for the Philco S-2000 a program to handle spectral data as direct input to a mathematical model for flashblindness. Also retinal burn data from laboratory tests are being analyzed in the light of similar data from weapons tests, and pretest estimates of retinal burn thresholds for designing weapons test flashblindness experiments are being prepared.

Intended to expand upon the efforts prescribed by Contract AF 41(609)-1978 to study the behavior of human subjects under high-stress conditions, Contract AF 41(609)-2442, also sponsored by the USAF School of Aerospace Medicine, requires primarily special instrumentation and data collection systems for several physiological studies. Program requirements include design, fabrication, and installation of psychomotor performance task equipment on a human centrifuge, a rotational flight simulator, and a B-47 simulator; linearization of a flowmeter to analyze the blood-flow pattern of stressed animals; installation of telemetry systems in the two simulators and the system signal checkout with human subjects aboard; and development and fabrication of a system capable of displaying, converting from analog to digital form, and printing out the data from nine physical and physiological parameters.